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MANAGEMENT OF WILD AND CULTURED

SEA BASS / BARRAMUNDI

(Lates calcarifer)

ACIAR PROCEEDINGS

No. 20

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Management of Wild and Cultured Sea Bass/Barramundi (*Lates calcarifer*)

Proceedings of an international workshop held at Darwin, N.T. Australia, 24–30 September 1986

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FOREWORD

Lates calcarifer, or Barramundi as it is called in Australia and Sea Bass in Asia, is a fish that has a widespread distribution and a variety of roles in the fisheries of the Indo-Pacific region. For example, Thailand is perhaps the world leader in many aspects of the culture of *L. calcarifer.* In South Asia and Australia the main activity has been in the wildstock fishery. Due to the geographical distribution of the species, only recently has there been interest shown in the detailed study of the biology of *L. calcarifer.* Indeed the research priorities established as a result of the Workshop indicate the need for further biological research to assist the traditional culture of the species and to get a better understanding of its behaviour under natural conditions.

The considerable interest and country participation in this workshop reflects the importance of barramundi as a valuable natural resource for many countries in the Indo-Pacific region. This workshop provided the first opportunity for scientists from the region to come together to share and exchange views on the various research priorities and production systems of this important species.

The purpose of the workshop was to identify the scientists currently involved in *Lates calcarifer* research and to establish research priorities for the development of the species as a cultured and/or wild fish. ACIAR was pleased to assist in bringing the scientists to Darwin and would like to thank the organising committee and to acknowledge the support given by Mr Nick Dondas, Minister of Ports and Fisheries, and members of his Department. The assistance of Peter Blake, Secretary of the Department, Wendy Flynn, Northern Territory Museum of Arts and Sciences, and Pam Griffin as Workshop Secretary, is gratefully acknowledged.

Finally, I would like to thank Reg MacIntyre of ACIAR, for his role in the efficient editing and production of this publication, which has been appreciated by all the participants.

J.R. McWilliam
Director
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Summary of Discussion and Recommendations

Summary of Discussion and Recommendations

i) General

1. The lack of an adequate knowledge base on all aspects of *Lates calcarifer* was identified as a major constraint to the management, development and protection of current and future wild and farmed fish resources.
2. There is a need for a central data base which can be readily accessed and added to by scientists, planners and fishery managers. Such a data base could be placed in existing fishery institutions and research organisations, and could be supplemented by a Newsletter which could assist in adding to and accessing the data base.
3. There is a need to collect and collate a bibliography of the available literature on *L. calcarifer* in order to appreciate the benefits of earlier research. Such a bibliography could form the first step in assembling a data base on *L. calcarifer*.
4. There is a need to conduct a socioeconomic study of the current value and potential development of the commercial, recreational and farmed *L. calcarifer* fisheries. The studies would be greatly benefited by a multidisciplinary approach.

ii) Biology of Wild Stock

1. It was recommended that the existing genetic diversity of *L. calcarifer* and related characteristics of maturity and sexuality be established throughout its natural worldwide distribution. The identification of individual population groups within the species would assist in the:
   — Identification of separate breeding stocks for capture fishery management;
   — Assessing the extent of inbreeding in hatchery stocks;
   — Establishment of the distribution and diversity of the world gene pool for *L. calcarifer* to enable selective domestication for culture;
   — Understanding of important biological characteristics between different stocks and climates.
2. The importance of the nursery inland habitat for wild larvae and fry should be further investigated, with particular emphasis on the cataloguing of these habitats and identification of their physical and biological characteristics in both Asia and Australia. In addition the monitoring of the loss of natural habitats by pollution and future alienation should be recorded.
3. Identification of the natural spawning grounds of *L. calcarifer* has a high priority in order to conserve the fish population, collect wild fish for culture purposes and to obtain more essential basic environmental and biological data of mature fish for stock assessment purposes.
4. The identification of the most critical survival stage of wild stock was thought to be essential for sound management practices. Once identified they could provide an important stock-monitoring tool. The impact of exploitation by traditional, commercial and/or recreational fishermen on these stages should be investigated.

iii) Management

1. The great variety of different management requirements, procedures and options existing in Asia, Australia and Papua New Guinea was noted. In many countries the *L. calcarifer* catch was part of a multispecies fishery of an artisanal and subsistence nature and in these cases statistics for management purposes were not readily available or obtainable. Accordingly, it is recommended that the collection of appropriate fisheries statistics such as catch and effort data should be encouraged to assist in fisheries management.
2. It was recommended that the potential advantages and disadvantages of enhancement of wild stocks by stocking with hatchery-bred fish should be

investigated, with particular emphasis on the possible ecological and genetic implications. Potential also exists in several countries for development of domestic or tourist-based recreational fisheries based on stocking of artificial waters where *L. calcarifer* does not occur naturally. The feasibility of such development, already demonstrated in Australia, should receive further research.

3. In view of the protandrous nature of *L. calcarifer,* there is a need for an assessment of the levels of protection required for large female fish in order to protect the breeding stock and prevent overfishing.
4. There is a need to evaluate the range of magnitude of the wild *L. calcarifer* catch in Asia and Australia and to determine appropriate and effective biological and socioeconomic indices to manage wild and cultured stocks. This should include investigation of the impact of collection of hatchery broodstock from wildstocks on natural recruitment.

iv Culture of *Lates calcarifer* — Breeding and Reproduction

1. A high research priority is to develop a better understanding of the hormonal physiology of *L. calcarifer* in cultured and wild fish. This study is to include:
   - — Factors and mechanisms of the sex-reversal;
   - — Identification of the environmental and biological factors responsible for hormonal changes of spawning fish, such as the nutritional condition of the broodstock.
2. A study is needed of the spawning behaviour to improve management practices, with particular emphasis on the identification of ripe fish.
3. Research emphasis should be placed on the further development of hormonally induced spawning for higher fertilisation and hatching rates and greater survivability of larvae. This should include the possibility of identifying and using external spawning stimuli, which could be applied to the water or feed.
4. Research should be carried out to prevent or delay the sexual reversion of the male to the female fish by hormonal and/or environmental manipulation.
5. Improved tank design for natural environmentally induced and artificially induced spawning is required for more efficient production.

v) Culture of *Lates calcarifer* — Larval Rearing and Nursery Phase

1. An intensive multidisciplinary research input is required to identify the factors that are involved in the high loss of larvae and fry between days 0–30. This should involve investigation of the biology and environmental interactions with particular emphasis on growth rates, nutrition and both non-infectious and infectious diseases.
2. The development of a monitoring checklist defining optimal environmental and nutritional parameters to determine the health status of larvae is recommended.
3. Research emphasis should be placed on improved husbandry practices for larval production such as tank design, water management, stocking density, etc.
4. Research is required on the development of the digestive physiology of larvae, in order to help ascertain the nutritional and feeding requirements of the larvae and the selection of a compatible low-cost artificial diet.

vi) Culture of *Lates calcarifer* — Pond and Cage Culture

1. Identification of desirable pond and cage site selection parameters to provide future development guidelines is a high priority. The selection of sites should take into account the opportunity costs, soil types and site availability which in turn would indicate whether cage or pond culture is preferable. Environmental impact of pond/cage cultures needs to be evaluated.
2. Research is needed to identify the optimal juvenile size for stocking ponds or cages to reduce the frequently observed low survival of fish soon after stocking at the start of the grow-out phase.

3. An evaluation in terms of production and socioeconomic benefits of a two-stage grow-out phase should be investigated in the countries with established *L. calcarifer* farms. Maintenance of optimal water quality is a problem throughout the Asian region and there is a need to improve management systems and water treatment (aeration and prophylactic treatment). The tolerance of *L. calcarifer* to various water quality parameters in ponds and cages needs to be determined. This will allow the development of 'early warning' systems for monitoring environmental changes.
4. Research is required on engineering aspects of ponds and cages for improved water circulation, flushing and feed utilisation. In the case of cage culture, reduction of bio-fouling problems was a priority.
5. The identification of other fish species that would be suitable as a feed source and which are compatible with *L. calcarifer* is a high priority.
6. A knowledge of the effects of differing culture conditions on the postharvest aspects of *L. calcarifer* is required as it is a high-valued product, with particular reference to taste quality, preservation and transport of live fish to markets.

vii) Culture of *Lates calcarifer* — Nutritional Aspects

1. The estimation of the nutritional requirements of the larval, fry, fingerling and grow-out stage of *L. calcarifer* is a high priority research project, which is essential for the further development of artificial feeds.
2. The establishment of the nutritional biochemical profiles and physiology of both wild and cultured fish is considered to be important in order to establish and monitor the nutritional status of wild and farmed fish.
3. The development of alternative feed sources for all developmental stages is a priority, either as a complete artificial food or as a supplement to enhance natural food. This will allow the formulation of a practical feeding regime for extensive, semi-intensive and intensive culture systems. The feeds developed should include as many low-cost ingredients as possible.
4. A study should be made on the feeding behaviour in wild and cultured fish which would assist in maximising feed efficiency. Combined with this study should be an investigation of the best form of presentation of artificial feeds and the best feeding regime.
5. Improved methods of culture and preservation need to be developed for natural feeds such as algae, rotifers, *Artemia* and fresh fish for the various *L. calcarifer* growth stages.
6. Research to determine optimal nutritional requirements for the sexual maturation and spawning of captive broodstock requires special attention.
7. The influence of feed type on growth rates, nutritional state and feed conversion rates at various temperatures and salinities needs to be investigated.

viii) Culture of *Lates calcarifer* — Fish Health

1. Research activities in the health of *L. calcarifer* should be focused on the prevention of diseases, using management and a sound knowledge of the biology of the host, the pathogens, toxins and the non-infectious causes that are detrimental to the growth and survival of the fish.
2. A multidisciplinary investigation is needed on the loss of production due to the cost of control measures, treatments and fish losses in existing farms of the region.
3. There is a need to identify the most susceptible developmental stage of wild and cultured *L. calcarifer* to diseases due to either infectious and/or non-infectious causes.
4. In order to successfully diagnose the disease processes and their aetiology in the developmental stages of *L. calcarifer*, there is a need to establish descriptions of normal tissues and an understanding of the normal protozoan and bacterial flora of the fish and water under specified production systems.

5. Research into specific diseases should be based on the socioeconomic importance of the specific diseases in each country. Two specific diseases that warrant further investigations are dermal ulcerative necrosis and vibriosis of *L. calcarifer*.
6. A detailed study of the physiological and pathological changes in *L. calcarifer* due to non-specific stress should be undertaken. As these are frequently the precursor to disease outbreaks, particular emphasis should be accorded to environmentally induced stress and protozoan infections.
7. The establishment of a regional authority for the collection, diagnosis, dissemination and advice on fish health matters was strongly recommended. Combined with this was the need to establish training facilities for fish health in the region.
8. It was recommended that emphasis be placed on the utilisation of existing animal health resources for specialised fish disease investigations involving biology, epidemiology, microbiology and pathology.

Research Activities in Australia and Asia

An Overview of *Lates calcarifer* in Australia and Asia

D.L. Grey*

Barramundi or sea bass, *Lates calcarifer* (Bloch), is an important coastal, estuarine and freshwater fish in the Indo-Pacific region.

It supports extensive commercial and recreational fisheries in Australia and Papua New Guinea and provides the basis of an extensive aquaculture industry in Asia, where it is also subject to wildstock exploitation.

The species is widely distributed from the Arabian Gulf to China and Taiwan, and to Papua New Guinea and northern Australia. It is generally regarded as a catadromous species although its life history shows some variation throughout its range.

The species has been the subject of considerable research in the last decade, most of which is clearly identifiable as either supporting the development of aquaculture or providing information relevant to wildstock management. These studies have revealed some differences in the morphology, life history and biology throughout its distribution which suggest significant intraspecific variation.

This paper provides a brief introduction to the species, its taxonomic situation, geographic distribution, life history and exploitation.

Taxonomy and Nomenclature

Barramundi was first described by Bloch (1790) from specimens received from Dutch merchants returning from the Indo-Pacific region. His type specimen was named *Holocentrus calcarifer* for the similarity between the preopercular spines and thorns ('calcarifer'; translating to 'thorn carrier'). The genus *Lates* (Cuvier and Valenciennes) was erected somewhat later (1828) to encompass other species including the closely related Nile perch (*L. niloticus* Linnaeus).

Although the species has always been included in the large order Perciformes and suborder Percoidei, or 'true perch,' its familial designation has had a variable status including allocation to Percinae (Day 1878), subfamily Centropominae (Boulenger 1895), Latinae (Fowler 1928), Serranidae (Fowler and Bean 1930), Latidae (Munro 1955, 1967) and Centropomidae (Katayama 1956). It is now generally considered that the genus *Lates* should be included in the family Centropomidae. Greenwood (1976) reviewed the family and included eight species within the genus *Lates* in the family, those being *L. calcarifer* and seven African species.

Several authors have noted the wide variability apparent between the original description and illustration of Bloch and other more recent descriptions (Reynolds 1978; Moore 1980). These include the presence or absence of teeth on the tongue and the number of transverse and lateral line scales. Unfortunately the type specimen of *L. calcarifer* appears to have been lost (Katayama et al. 1977) and these differences will not be resolved.

Dunstan (1959) noted, however, that there were differences in body proportions both within and between localities. His later work (Dunstan 1962) also identified morphological differences between the Papuan and Australian fish and those of previous descriptions. Variation in coloration between juvenile and adult fish and between fish in salt and fresh water was also reported by Dunstan (1962) and Reynolds (1978). Notwithstanding the variability reported to that time, Greenwood (1976) proposed only a single species of *Lates* throughout the Indo-Pacific.

The study by Katayama et al. (1977) resurrected some of the controversy surrounding the identity of *Lates calcarifer*. These authors examined fish from Australia, Japan and Taiwan and concluded that there were substantial differences in the Japanese specimens. This led them to propose that the Australian form should be called *Lates cavifrons* in accordance with the original description by Alleyne and MacLeay (1877). However Katayama et al. (1977) did not propose a specific name for their Japanese form and, by default, the name *Lates calcarifer* appeared to become unattached. Moore (1979) noted that Katayama et al. (1977) considered that Bloch's original specimen was collected from Indonesia. Assuming this was the case, then in view of the

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continuous distribution of *Lates* through the Indonesian Archipelago to Papua New Guinea and Australia, it is likely that the species in these countries is synonymous with that described by Bloch. The matter was clarified somewhat when Katayama and Taki (1984) described a new species from the 'akame' referred to in Katayama et al. (1977), designating it *Lates japonicus*.

As is to be expected with a species that occupies a wide geographic range, *Lates calcarifer* comes under a diverse group of common names. Although 'barramundi' is the accepted common name in Australia (derived from 'burramundi' an Aboriginal word meaning large scales), it has been variously called giant perch, palmer, cock-up and barramundi. It is known as 'giant perch' and 'anama' in Papua New Guinea, 'sea bass' and 'bhekti' in India, 'seabass' in Thailand and the Philippines, 'akame' in Japan and 'seabass' in Indonesia, to list but a few (Dunstan 1962; Rabanal and Soesanto 1982).

The species is quite distinct from other members of the family Centropomidae in the Indo-Pacific region with the exception of *Psammoperca waigiensis* (Cuvier), a much less common and wholly marine species, and *L. japonicus*. There is thus very little confusion surrounding the application of the common name in each country.

A full taxonomic description of *Lates calcarifer* (Bloch) is provided in Appendix 1 (FAO 1974).

Distribution

Lates calcarifer is widely distributed in coastal and fresh waters throughout the Indo-West Pacific region including India, Burma, Sri Lanka, Bangladesh, Malay Peninsula, Java, Borneo, Celebes, Philippines, Papua New Guinea, northern Australia, southern China and Taiwan (Greenwood 1976; Moore 1980) (see Fig. 1).

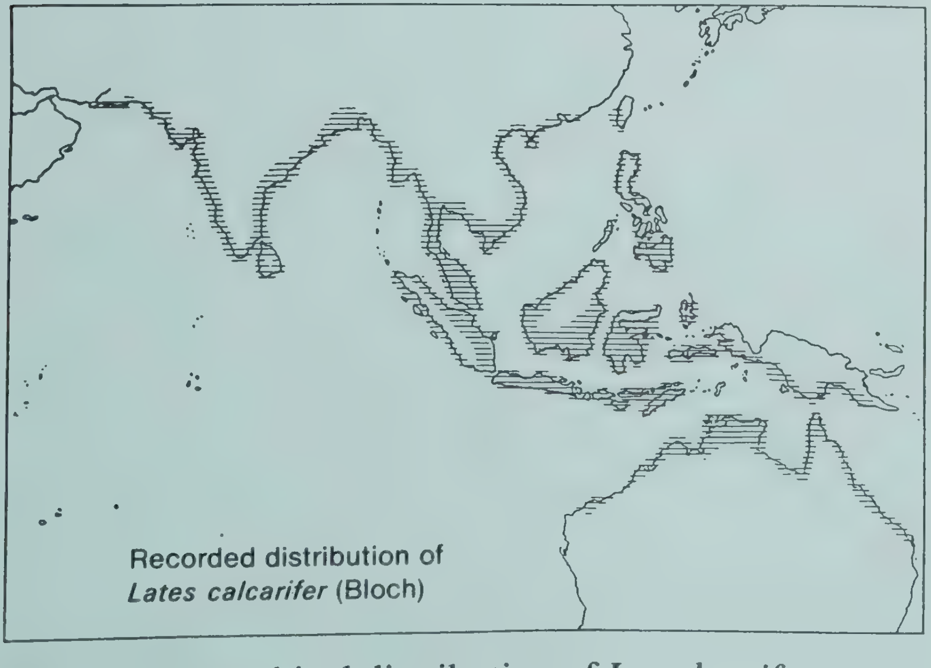

Fig. 1. Geographical distribution of *L. calcarifer*.

The western limit of its distribution appears to be the Persian Gulf (Zugmayer 1913) although it is not of commercial importance according to Randall et al. (1978) who made extensive collections in the eight countries surrounding the Gulf. The eastern limit of the distribution of *Lates calcarifer* is the southeast tip of the Papua New Guinea mainland while it is distributed north to Amoy (Hsia-men) at latitude 24°30′N on the Chinese mainland (Dunstan 1962). The reference to records from Japan in Greenwood (1976) is no longer valid as Katayama and Taki (1984) have renamed these as *Lates japonicus*. The southern limit of the distribution of *Lates calcarifer* is the Australian mainland, being the Noosa River (26°30′S) on the east coast (Grant 1982) and the Ashburton River (22°30′S) on the west coast (Morrissy 1985).

The limits to the distribution are probably defined by either lack of suitable habitat, competition with overlapping species or temperature and salinity. The lack of large rivers and fresh water to the west and the lack of continental land masses, and thus rivers, to the east would limit further distribution past these extremes. With regard to the latitudinal limits, these are most likely due to temperature (China and Taiwan being on similar latitudes to the Ashburton and Noosa rivers) and/or competition with similar overlapping temperate species, e.g. *Lateolabrax* to the north and *Macquaria (Percalates)* to the south.

Recent research in Australia and Asia has revealed that eggs, larval and juvenile stages have a narrower range of tolerance of salinity and temperature than adults (Russell and Garrett 1983, 1985; Tattanon and Maneewongsa 1982). This factor is undoubtedly of significance in determining the species distribution.

Within its range, *Lates calcarifer* occupies both fresh and salt water including streams, lakes, billabongs, estuaries and adjacent coastal waters. It is rarely taken at any distance from land and is generally only found in waters subject to freshwater influence.

Biology and Life History

Studies on *Lates calcarifer* in northern Australia and Papua New Guinea have identified that it has a complex life history, being a protandrous hermaphrodite and catadromous (Moore 1979, 1980, 1982; Moore and Reynolds 1982; Reynolds and Moore 1982; Russell and Garrett 1983, 1985; Griffin 1985, 1986; Davis 1982, 1985).

In these areas, spawning occurs in brackish waters (28–36‰ salinity) near the mouths of rivers, commencing in August or September through until February. Movement to the spawning areas and maturation of gonads is thought to be triggered by an increase in water temperature which occurs at the end of the dry season (southeast monsoon). There is a tidal-based monthly cycle of spawning, with postlarvae entering coastal swamps on the peak spring tides. As the wet season (northwest monsoon) develops, these swamps

and adjacent floodplains back up with fresh water and the young barramundi remain in this safe, productive environment until floodwaters recede around March or April (Davis 1985).

At this time, the young-of-the-year fish move upstream to the upper reaches of the river where they generally remain until they are 3–4 years of age (60–70 cm TL or 2.6–4.2 kg). At this time they reach sexual maturity as males and at the end of the next dry season will migrate downstream to spawn, depending on access to tidal waters (Fig. 2). These fish remain in the tidal waters of the river, and each male will participate in spawning several times before changing sex at between 6 and 8 years to become female (protandry). At this age, the fish are 85–100 cm in length and between 7 and 12 kg (Davis 1982).

Australia/Papua New Guinea fish in some features of their maturation, migration and spawning (Palmer and Arthington 1986; MacKinnon 1984). Although some of these differences can be attributed to variations in climate and topography throughout the range of the species the reasons for others are less apparent. Moore (1980) and Davis (1982) reported that males matured at between 510 and 700 mm and between 550 and 680 mm respectively in Papua New Guinea and northern Australia. This corresponds with the size of mature males used by Wongsomnuk and Manevonk (1973) in Thailand and those reported by Patnaik and Jena (1976) in India. By contrast, the reported size of mature females is somewhat different. Patnaik and Jena report the smallest female encountered at 700 mm in India, and Wongsomnuk and Manevonk (1973) used females from 640 to 850 mm for spawning experi-

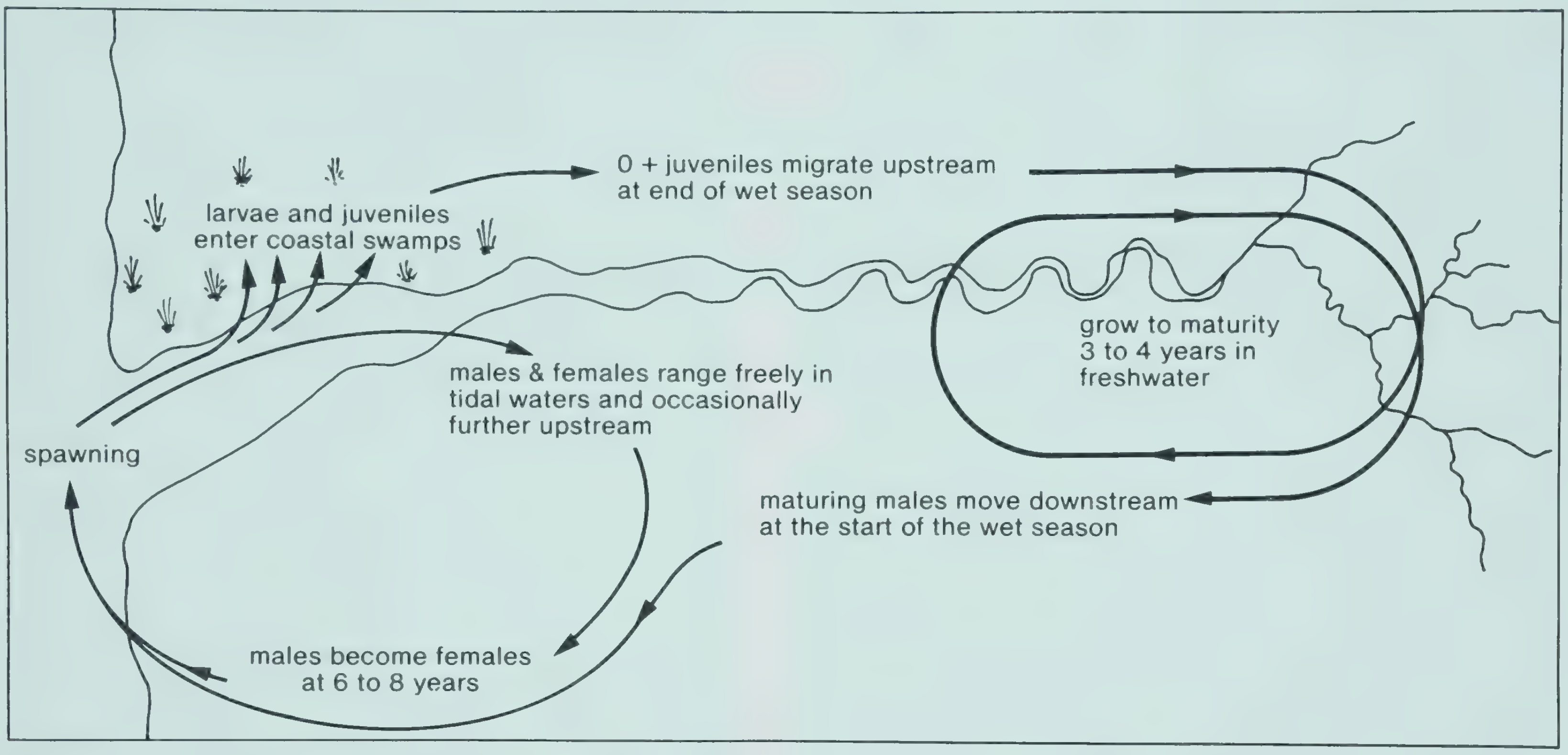

Fig. 2. Generalised life history of barramundi *(L.calcarifer)* in Australia.

Although this is accepted as the general model for the majority of stocks of barramundi in Australia and Papua New Guinea, Davis (1984a) described populations of sexually precocious *Lates calcarifer* from the Gulf of Carpentaria. These fish were changing sex at a much younger age (4–5 years) and smaller size (30–50 cm).

Australian studies on the reproductive capacity of barramundi indicate that the species is very fecund, producing up to 10 million eggs at 100 cm and 30–40 million eggs at 120 cm (Davis 1984b).

The strong association between the life cycle of *Lates calcarifer* and the monsoon cycle in Australia and Papua New Guinea waters is also identified in Thailand (Yingthavorn 1951; Barlow 1981). The species exhibits similar spawning behaviour in Asia, including migrations of adults to spawning areas and movements of larvae and juveniles upstream. However, there are differences between Asia, and

ments. Female *Lates calcarifer* used for induced spawning experiments in Thailand weighed about 5 kg (Maneewongsa 1982). While several observations have been reported on the size at first maturity of female *Lates calcarifer* in Asia, none have mentioned the sex reversal reported from Australia (Davis 1982) and Papua New Guinea (Moore 1979). Davis (1982) inferred that the age at which barramundi undergo transition from male to female may be reduced under heavy fishing pressure, and thus it could be that the apparent differences between Asian and Australia/ Papua New Guinea barramundi are artefacts resulting from a long history of intensive fishing. It is interesting to note that there is no reference in the literature to sex reversal in Asian barramundi, although some reports indicate that some 80% of broodstock fish used in Taiwan undergo sex reversal (Blake, personal communication).

Several others have reported on the food and feeding

of wildstock *Lates calcarifer* including Dunstan (1959, 1962), Moore (1982), Russell and Garrett (1983), Patnaik and Jena (1976), Tait (1981) and Davis (1985). These have confirmed that the species is cannibalistic and predacious throughout its life cycle. As it is a piscivore and cannibalistic (Davis 1985) it is not ideal for polyculture and stringent size grading is necessary for monoculture. Successful intensive culture of *Lates calcarifer* requires large amounts of trash fish or the development of a suitable artificial feed. Research on aspects of food and feeding of cultured *Lates calcarifer* has been reported by Maneewongsa and Tattanon (1982), Kosutarak (1984), Chou (1984, 1985), FAO (1982) and IDRC (1985) and is continuing in a number of institutions throughout Asia and more recently in Australia (Newby, personal communication).

Fishery Production

Capture Fisheries

Lates calcarifer is a popular and highly valued food fish throughout the Indo-Pacific region, which commands a high market price whenever it is available. It has the advantage of a fast growth rate, large size and delicate-flavoured flesh. It comprises a varying component of the estuarine scale-fish fishery for most countries in the Indo-Pacific region, and is always in high demand.

There are, however, very little data available on the production of this species from capture fisheries, as it is often included with other species in those areas where landings are declared, or wildstock landings are included with production from aquaculture. Total world production for 1982 (FAO 1984) was estimated at 18 099 t (Table 1) but this includes a substantial contribution from aquaculture.

In 1978, FAO (1984) reported a world production of 12 385 t of which SEAFDEC reports Southeast Asia as producing 10 192 t, Indonesia 9314, Malaysia 147, and Philippines 731.

There were no data available on production from capture fisheries in Brunei, Taiwan, Hong Kong, Kampuchea, Singapore, Thailand and Vietnam for that period (Rabanal and Soesanto 1982).

Commercial production of barramundi from Australia increased significantly from the 1970s and totalled 943 t liveweight in 1979–80. Of this, 690 t came from the Northern Territory, 227 from Queensland and 25 from Western Australia (Australian Bureau of Statistics 1984).

The increase in production continued until the introduction of management regulations in the Northern Territory and Queensland. These were introduced to control the increasing levels of exploitation by commercial fishermen (Grey 1986; Rohan et al. 1981; Anon 1982) as identified in part by improvements in catch and effort data collection (Grey and Griffin 1979; Quinn 1984). Production of barramundi from New Guinea has fluctuated in recent years (Coates, personal communication) and was 308 t in 1982 (FAO 1984).

The methods of capture used in the fisheries include bottom trawls, seines, gillnets, stake traps, hook and line and lift net.

Culture Fisheries

The popularity and demand for *Lates calcarifer* made it an obvious choice for the development of aquaculture technology. Apart from the characteristics that endear it to the consumer, the fish is fast-growing and euryhaline. The latter fact is seen as a valuable attribute for a species subject to pond and cage culture under monsoonal conditions (Masuo 1984; NICA 1986). Techniques for the culture of barramundi were developed in Thailand in the early 1970s (Wongsomnuk and Manevonk 1973) and considerable progress in aquaculture techniques for the species has been achieved since that time. MacKinnon (1984) reported that 20 million fry were produced in Thailand in 1981 and Sirikul (1982) reported that commercial aquaculture of barramundi in Thailand produced over 300 t in the same year.

Since the development of the culture techniques in

Table 1. Nominal world catch (landings) of *Lates calcarifer* (FAO 1984, 1985).

Fishing area	1979	1980	1981	1982	1983
Indonesia (inland waters)	745	850	883	757	1 060
Indonesia (marine)	8 456	10 938	9 845	12 743	9 950
Pakistan	528	457	1 895	3 018	2 990*
Malaysia	—	—	—	134	446
Papua New Guinea	207	221	308	308*	219
Australia	1 492	942	1 039	1 139	730*
Total:	11 428	13 408	13 970	18 099*	14 895*

* Data estimated or subject to revision.

Thailand, aquaculture of barramundi has expanded considerably with culture operations being undertaken in Philippines, Indonesia, Malaysia, Singapore, Burma, India, Vietnam, Kampuchea, Taiwan and China and more recently in Australia. Many of these countries are supporting active research into culture techniques for barramundi (FAO 1982; NICA 1986; Fortes 1985). There is a paucity of aquaculture production data on barramundi throughout Asia, primarily as the data are often not dissociated from wild stock landings. Indonesia reported 571 t of product produced from 'brackish water pond culture' for 1978 (Rabanal and Soesanto 1982) and 1060 t of product from 'inland waters' in 1983 (FAO 1985).

Recreational Fisheries

Barramundi is a recognised game fish under the International Game Fishing Association rules and is highly regarded by recreational fishermen and trophy hunters alike for its eating and angling quality.

In Australia, recreational fishing is a very popular pastime and the expansion of the recreational fishery for barramundi is being facilitated by the development of tourist infrastructure and improvement in access to remote localities. Fishing charter and safari operations, aimed primarily at barramundi, have increased significantly in northern Australia in recent years.

Recreational fishing for barramundi is of significant economic importance in parts of Australia. A survey of recreational fishing for barramundi in the Northern Territory (Griffin 1979, 1982) revealed that the annual value of the recreational barramundi fishery was of the same magnitude as the commercial catch. As a consequence, management regulations being introduced to the fishery take account of the recreational component.

Discussion

The foregoing briefly reviews some of the current knowledge of sea bass/barramundi in Asia and Australia. Although the species is common to the Indian subcontinent, Southeast Asia, China, Papua New Guinea and Australia, there are many contrasts in its methods of exploitation through the Indo-Pacific region. These methods vary from intensive culture using advanced techniques to culture utilising wild stocks and to wildstock fisheries. They further contrast in Australia where the level of recreational fishing is a significant factor in the exploitation of the wild stocks.

The review identifies apparent divergences in the behaviour, morphology, reproduction and size at sexual maturity of the species throughout its range. For this reason alone there would be justification in further study of the species and those aspects of its life history which are so variable. However, in view of the current importance and the obvious further potential of aquaculture of the species, it warrants further research.

Much of the biology and life history of the wildstock resources in Australia and Papua New Guinea has been documented, and this will no doubt lead to a better understanding of the species for aquaculture research. However, in light of the increasing trends to full or over-exploitation of barramundi wildstocks in world fisheries it is apparent that aquaculture of the species will become increasingly important.

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Appendix 1
Lates calcarifer Bloch

Taxonomic classification

Phylum Chordata
Subphylum Vertebrata
Class Pisces
Subclass Teleostomi
Order Perciformes
Family Centropomidae
Genus *Lates*
Species *Lates calcarifer* (Bloch)

Taxonomic description (FAO 1974)

Body elongate, compressed, with a deep caudal peduncle. Head pointed, with concave dorsal profile becoming convex in front of dorsal fin. Mouth large, slightly oblique, upper jaw reaching to behind eye; teeth villiform, no canines present. Lower edge of pre-operculum with a strong spine; operculum with a small spine and with a serrated flap above origin of lateral line. Dorsal fin with 7–9 spines and 10–11 soft rays; a very deep notch almost dividing spiny from soft part of fin; pectoral fin short and rounded, several short, strong serrations above its base; dorsal and anal fins both have scaly sheaths; anal fin rounded, with 3 spines and 7–8 soft rays; caudal fin rounded. Scales large, ctenoid (rough to touch).

Colour: two phases, either olive brown above with silver sides and belly (usually juveniles) or green/blue above and silver below. No spots or bars present on fins or body.

Biology of Wildstock *Lates calcarifer* in Northern Australia

T.L.O. Davis*

A premanagement study of barramundi, *Lates calcarifer,* was initiated jointly by the Commonwealth Scientific and Industrial Research Organization (CSIRO) Division of Fisheries Research, the Queensland Department of Primary Industry Fisheries Research Branch, and the Northern Territory Department of Ports and Fisheries in 1977. This study was funded largely by grants from the Fisheries Research Trust Account. CSIRO's research on barramundi was first conducted in the rivers and foreshores of Van Diemen Gulf in 1978 and extended in 1979 to include rivers of the east Gulf of Carpentaria. Field work was completed in June 1980. The biological material and data were analysed at the Division's Headquarters which were then located at Cronulla, New South Wales.

CSIRO's aim was to obtain basic information on the biology and population parameters of barramundi necessary for the rational management of the commercial and recreational fisheries. We investigated sexuality, maturity, fecundity, seasonal reproductive cycles, larval and juvenile distribution, diet, growth, and migration patterns of barramundi, and compared these parameters in populations from different river systems. A tagging program provided information on growth, movements and estimates of fishing mortality in rivers of Van Diemen Gulf. The results of this research are reviewed in this paper.

Study Area

Barramundi were sampled and tagged in Van Diemen Gulf in the Mary, West Alligator, South Alligator and East Alligator rivers. In the Gulf of Carpentaria, biological samples were obtained from the Norman, Smithburn and Gilbert rivers and, on two occasions, from most rivers along the entire east coast. These rivers are all strongly influenced by two distinct seasons, the wet and the dry. The timing and magnitude of these seasons vary between years and localities. In the wet season, which is caused by the northwest monsoons during summer, the low plains are extensively flooded, billabongs open to the sea, and the salinity of coastal waters is markedly reduced. During the dry winter season, which is associated with southeast trade winds, the flood plains dry out, billabongs are isolated and the salinity of coastal waters increases. The wet season is a period of high productivity as the vast areas of freshly inundated floodplain provide ideal growing conditions for aquatic macrophytes and associated fauna.

Reproductive Biology

Sex Inversion

Marked differences in the length-frequency distribution between sexes in wild populations of barramundi and subsequent biopsy examinations on pond-held fish led Moore (1979) to conclude that barramundi in western Papua were protandrous hermaphrodites. Similar sex ratios were found in barramundi populations in rivers of Van Diemen Gulf and the Gulf of Carpentaria (Davis 1982). Females were generally absent in the smaller length-classes but predominated in the larger length-classes (Fig. 1). However, there was considerable variation among populations from different areas. Barramundi from Van Diemen Gulf were apparently changing sex at a slightly larger size than were fish from the southeast Gulf of Carpentaria (Davis 1982), and a sexually precocious population in the northeast Gulf of Carpentaria was changing sex when almost half the size of other fish (Davis 1984a).

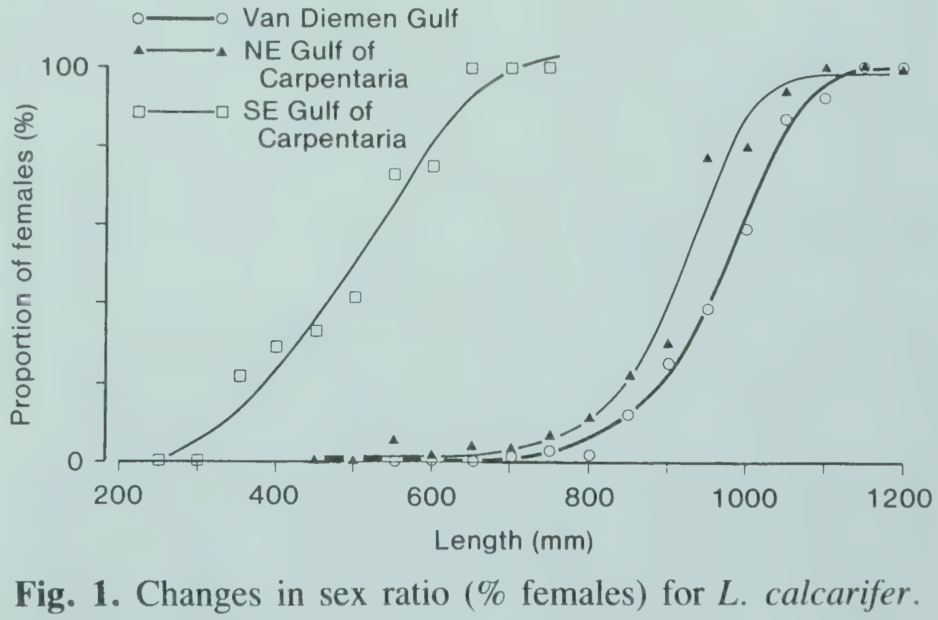

Fig. 1. Changes in sex ratio (% females) for *L. calcarifer*. Fish were grouped into 50 mm length classes.

Gompertz curves were fitted to the sex ratio/length data. The point of inflection, representing the length at which most males changed to females provided an

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objective means of comparing populations. In Van Dieman Gulf fish this point was reached at 1002 mm TL; in the southeast Gulf of Carpentaria at 936 mm TL; in the northeast Gulf at 535 mm TL.

The histological events associated with gonad maturation in male and female barramundi and the process of sex inversion are described in Davis (1982). Gonads in the process of changing sex cannot be detected macroscopically. By the time the external appearance of the gonad has changed, no spermatogenetic tissue remains. The only reliable way to detect transitional stages is by the routine examination of histological sections stained with haematoxylin and eosin. The highly basophilic cytoplasm of early perinucleolus oocytes makes them readily distinguishable from other cell types in the testis.

In Van Diemen Gulf, 10 transitional stages were detected after histological examination of 304 testes, and in the southeast Gulf of Carpentaria, 29 stages were found after examining 322 testes. The gonads of the northern, precocious, fish were not taken at the appropriate time of year to observe transitional stages. The lengths of transitional males in Van Diemen Gulf (mean 907 mm TL, range 840–970 mm, and 4–8 years old) were significantly larger ($t=5.15$,d.f.$=37$, $P<0.001$) than those in the southeast Gulf of Carpentaria (mean 820 mm TL, range 680–900 mm, and 3–7 years old), although the mean ages of the two groups were not significantly different ($t=0.23$,d.f.$=31$, $P>0.8$). Transitional males are slightly smaller (91–93%) than the point of inflection of the Gompertz curves fitted to sex ratio data. Similarly, the mean lengths of the very few transitional males detected by Moore (1980) in Papua New Guinea barramundi were 96% of the point of inflection calculated using the sex ratio/length data of Reynolds (1978). This suggests that predictions based on the sex ratio/length relationship in different populations may be a reliable indication of the size at which most fish are changing sex. This is particularly useful when direct histological observations are not practicable or possible (e.g. samples are unavailable at the appropriate time of year). Using this relationship I predicted that the mean length of sex-inverting males in the sexually precocious population in northeast Gulf of Carpentaria would be about 490 mm TL (Davis 1984a).

Sex inversion is intimately linked with the spawning season as females are derived from post-spawning males, and the transition is completed shortly after spawning (Davis 1982). In Van Diemen Gulf, transitional stages were detected from October to January, and in the Gulf of Carpentaria, transitions were observed from October to March (Davis 1982, Table 2). Newly formed females, identifiable for a brief period after sex inversion by the absence of perinucleolus-stage oocytes, occurred one month after sex-inverting males had been recorded. As the gonads of newly formed females develop rapidly and are soon indistinguishable from those of previously spawned females, it is likely that they mature in time to spawn during the season following sex inversion.

All but one of the 39 transitional males detected in Van Diemen Gulf and in the Gulf of Carpentaria were captured in tidal waters. This is in contrast to the situation in Papua New Guinea, where sex inversion possibly takes place in inland waters (Moore 1979). Australian barramundi do not undergo well-defined spawning and post-spawning migrations, unlike those in Papua New Guinea (Reynolds and Moore 1973; Moore 1980). Consequently, in Van Diemen Gulf and Gulf of Carpentaria waters, post-spawning fish of the size most likely to change sex tend to move no further inland than the upper tidal limits of creeks and rivers, whereas in Papua New Guinea, they migrate inland immediately after spawning.

Primary Females

Not all females are derived from males. Possibly a very small percentage of females develop directly from immature fish. Moore (1979) captured a single 2-year-old 420-mm TL female, which was smaller than the size at which males mature, and much smaller than the next smallest female, a 5-year-old at 730 mm TL. Primary females were observed in the sexually precocious population in the northeast Gulf of Carpentaria (Davis 1984a). They were less than a year old, precluding the possibility that they were derived from functional males. In most populations, because the gonads of primary and secondary females are indistinguishable from each other, only females too young to have been functional males in the previous breeding season can be identified as primary females.

Synchronous Hermaphrodites

Of 880 barramundi whose gonads were examined histologically, three were considered to be synchronous hermaphrodites rather than transitional males, as their gonads contained well-developed testicular as well as ovarian tissue (Davis 1982). A low incidence of synchronous hermaphroditism was also observed in Papua New Guinea barramundi (Moore 1979). A small percentage of abnormalities of this type occur in many gonochoristic species; its occurrence in sequential hermaphrodites is therefore unexceptional.

Size at Maturity

The testes first become distinguishable macroscopically by the appearance of furrows in their ventral surface, at which time they are semi-transparent, strap-like, very thin and often bordered by fat. This stage is first recognisable in males 250–350 mm TL (Davis 1982). Mature males (i.e. those that were either actively producing spermatozoa or had recently spawned) first appeared at 600 mm TL in Van Diemen Gulf

samples, 550 mm TL in the southeast Gulf of Carpentaria (Davis 1982, Table 1) and 290 mm TL in sexually precocious barramundi in the northeast Gulf of Carpentaria (Davis 1984a). Males in the first two areas mature between 3 and 5 years old, whereas the sexually precocious fish mature in their first or second year.

Some fish judged to be immature by the poor development of their testes may in fact be mature but in a quiescent phase. I have observed retarded development of gonads in both male and female barramundi in landlocked freshwater habitats (Davis 1985a). Until these fish reach coastal waters (which is possible during wet season flooding), they do not undergo the normal seasonal pattern of gonadal development. Moore (1982) also noted delayed gonadal development in pre-migratory fish in inland waters of Papua New Guinea. Several males larger than 1000 mm TL had quiescent testes totally devoid of spermatogenic tissue. These unusual males appear to be senile, unreproductive fish; possibly some males never undergo sex inversion. The large size range of spermatogenically active males (550–1050 mm TL) also suggests that they function as males for one or more spawning seasons before changing sex. However, sex inversion and size at maturity are linked, in that females are derived from post-spawning rather than immature males.

Fecundity

The fecundity of 29 barramundi ranging in length from 480 to 1350 mm TL was estimated with an automatic particle counter (Davis 1984b). An exponential curve relating fecundity ($F \approx x10^6$) and length L,mm) was fitted to the data:

$$F = 0.3089e^{0.0035L} \quad (r^2 = 0.822).$$

The relationship between fecundity and weight (W,g) was determined as:

$$F = 0.3089\exp(0.148W^{0.3391}).$$

The estimates for large fish were far more variable than those for smaller fish. For example, females of 1220 and 1240 mm TL contained an estimated 15.3×10^6 and 45.7×10^6 eggs, respectively. There were no apparent differences between fish from Van Diemen Gulf, the Gulf of Carpentaria, or the sexually precocious population. As histological examination of the ovaries used in fecundity determinations showed no evidence of partial spawning (the specimens being obtained before the spawning season), these estimates probably represent the total annual production of eggs. However, this does not preclude barramundi from being batch spawners. There are suggestions that large barramundi in Thailand spawn more than once in a season (Barlow 1981), and Moore (1980) considered that some barramundi in Papua New Guinea spawn several times within a few days.

Reproductive Cycle

Barramundi undergo a prolonged breeding season that starts just before the summer monsoon (Davis 1985a). In Van Diemen Gulf, the temporal pattern of larval abundance in the 1978–79 breeding season reflected essentially the same pattern of spawning as that depicted by the gonadal cycle of mature fish (see Davis 1985a). In the Murgenella-East Alligator region, spawning was detected in September, October and February. In the 1979–80 breeding season, the movements of juvenile barramundi into the Buffalo Creek–Leanyer Swamp complex near Darwin demonstrated that spawning first took place in this region in September and continued until February.

In the Gulf of Carpentaria, spawning was first detected when spent fish were taken in December 1979. Juveniles were not found until 1 January 1980. The size range of the juveniles suggested that, while most had been spawned in late December, some of the larger individuals must have been spawned earlier. The presence of spent fish and small juveniles in samples indicated that the spawning period continued to March. The timing and duration of the following spawning season (1980–81) was similar, as evidenced by the pattern of trapping of juvenile barramundi in the Norman River (Russell and Garrett 1983).

The timing and duration of breeding appear to vary considerably among regions, rivers and years,. but essentially it is synchronised so that juveniles can take advantage of the aquatic habitat that results from rains in the monsoon season. In the Gulf of Carpentaria, supralittoral habitats in the form of tidal pools, gutters and some swamp are important nursery areas for juvenile barramundi (Davis 1985a; Russell and Garrett 1983). In Van Diemen Gulf, where this type of habitat is less extensive, floodplain and billabong systems many kilometres from the coast become the important nursery areas. Movement up these rivers is greatly assisted by the large spring tides (7 m variation) at this time of year. These vast aquatic habitats, formed during the summer months, provide juvenile barramundi with an almost predator-free, prey-rich environment promoting rapid growth and improved survival; it does, however, have to be vacated when it dries later in the year.

The prolonged spawning season appears to be the result of landlocked fish arriving late on the spawning grounds when flooding has occurred late in the wet season. High salinity appears to be the main requirement of spawning grounds. All the significant hauls of barramundi larvae in Van Diemen Gulf were made when salinities were 30% or higher (Davis 1985a, Table 2). Suitable salinities have been observed on the mudflats adjacent to the mouths of most rivers during the first months of the spawning season in northern Australia. The position of some hauls of larvae (for

example, the 12 larvae 4.3–6.6 mm TL captured 77 km upstream in the South Alligator River at low tide) indicates that spawning can also take place well upstream provided salinities are high. A general catadromous migration to specific spawning grounds because of inadequate salinities locally, as observed in Papua New Guinea (Moore 1982), is not necessary in rivers examined in northern Australia. As a consequence, juveniles in northern Australia colonise all sections of rivers normally occupied by barramundi within their first year (Davis 1985a; Russell and Garrett 1985). In contrast, juveniles in Papua New Guinea take over a year to reach inland waters, after having migrated at least 100 km along the coast (Moore and Reynolds 1982).

Observations that barramundi spawn locally in rivers rather than on common spawning grounds in northern Australia are consistent with recent biochemical genetic evidence of stock heterogeneity (Shaklee and Salini 1985). Recruitment into major river systems would depend largely on the successful spawning of local populations.

It is unlikely that the late spawning of landlocked fish results in significant recruitment during normal seasons. Not only do the relative numbers of late spawners appear to be low, but the juveniles of later spawners would be less likely to survive than those spawned earlier. Juveniles from late spawnings would not find predator-free nursery areas, as these areas would already be occupied by larger barramundi; the nursery areas would then become a hostile environment. Barramundi are cannibalistic and capable of eating prey barramundi up to half their own length (Davis 1985b). However, if the monsoon is delayed or interrupted, juveniles that were spawned early could perish if nursery areas either did not form or dried out. In this situation, juveniles from late spawnings would be able to colonise these nursery areas, which would not provide the same predator-free, food-rich habitat normally used by juveniles spawned early. Thus the spawning of landlocked fish could result in significant juvenile recruitment in years of erratic monsoonal activity.

Age and Growth

The growth of barramundi was investigated by tagging and scale reading in five major river systems in northern Austalia (Davis and Kirkwood 1984), and by scale reading in the sexually precocious population of the northeast Gulf of Carpentaria (Davis 1984a).

Validation of Scale Reading

Checks, which were well defined, were characterised by crossing over of circuli, particularly towards the posterior ctenoid field. Pairs of scales taken from fish at the time of tagging and upon recapture were used to verify that checks were laid down annually in rivers of Van Diemen Gulf. Checks were formed between September and December, depending on the particular river and year. While the timing of check formation was variable, most fish formed one check each year. Only 4 of the 110 recaptured fish that were examined had not formed the number of checks appropriate for the period of liberty (Davis and Kirkwood 1984). Seasonal data on marginal scale increments also verified that checks were formed annually in fish from the Norman River. Several factors may be responsible for check formation. The well-defined crossing-over of a number of circuli to form each annulus, which is exhibited by most fish, suggests that they have a prolonged period of low physiological condition each year. These annuli become defined after normal or optimal growth resumes. Ageing by scales has been used successfully in the closely related tropical species *Lates niloticus* in Lake Chad, Nigeria (Hopson 1965, 1972). Jensen (1957) had previously demonstrated that the first annulus in young *L. niloticus* is formed during winter in Lake Mariout, Egypt. In both these areas the winter checks were due to low water temperatures. Coulter (1976) postulated that checks in the scales of *L. mariae* from Lake Tanganyika, where there is only a 5°C annual range in temperature, could be due to annual variations in spawning and condition. Barramundi in northern Australia may, in addition, be subject to annual migrations and extreme salinity changes, either of which could produce checks. All of these factors would come into effect sometime between the end of the dry season and the first significant floods (September–January).

Growth

Mean lengths at age for fish from each river were obtained by scale reading (Table 1). Lengths were only back-calculated to the last annulus to eliminate any possible systematic errors of the back-calculation method (e.g. the presence of Lee's phenomenon, Ricker 1969), to ensure that each observation of length-at-age was statistically independent, and to provide length-at-age data unconfounded by differences in the time of year of sampling. Von Bertalanffy growth curve parameters and their standard errors (Table 2) were calculated separately for data from each river by direct, non-linear, least squares estimation in a manner similar to that of Kirkwood (1983).

The growth of sexually precocious barramundi from the northeast Gulf of Carpentaria was markedly slower than the growth of fish from all other rivers. Stunting in the northeast Gulf barramundi was more obvious in older fish, which suggests that energy had been channeled into gonadal growth at the expense of somatic growth at a relatively early age.

Likelihood ratio tests (Kirkwood 1983) were used to compare the growth curves from each of the five rivers holding normally maturing populations of fish. All

pairwise comparisons of growth curves were significant at the 1% level except those between Mary and East Alligator and Mary and Norman rivers (Davis and Kirkwood 1984). A one-way analysis of variance also indicated significant differences in mean lengths at each age from 1 to 5 years for these rivers ($P<0.01$). In view of the significant differences found between growth data for different rivers, no reliable overall growth curve could be obtained.

Table 1. Mean lengths at age back-calculated to the latest annulus for samples from each river. Only means of five or more lengths at each age are presented.

Age (years)	Mary	West Alligator	South Alligator	East Alligator	Norman	Northeast Gulf
1	334	310	353	324	314	291
2	486	472	493	510	527	407
3	594	565	579	599	613	456
4	671	632	638	672	685	505
5	769	683	718	740	776	618
6	880	806	765	873	828	
7	973			987	944	670
8	1002			1015	1063	
9	1031			1020		
10					1121	

Table 2. Estimated parameters (± s.e.) of von Bertalanffy growth curve for barramundi from different rivers.

River	Number	$L\infty$	K	t_0
Mary	438	1425(121)	0.125(0.020)	–1.26(0.24)
West Alligator	346	868 (44)	0.296 (0.039)	–0.53(0.13)
South Alligator	217	1604 (437)	0.088 (0.038)	–2.01 (044)
East Alligator	522	1775 (205)	0.085 (0.0117)	–1.76 (0.28)
Norman	459	1449 (62)	0.125 (0.011)	–1.27 (0.15)
Northeast Gulf	138	886 (106)	0.179 (0.046)	–1.26 (0.30)

The growth of barramundi varied markedly between and within rivers. It is likely that the observed variability was a reflection of the different environmental conditions experienced by barramundi in the different rivers. It is also possible that growth achieved in different years within the same river varied for the same reasons. This would explain the often substantial and unpredictable variability in annual growth increments of fish from the same rivers.

Food Habits

Examination of the diet of barramundi, based on 3684 specimens 4–1200 mm TL taken from Van Diemen Gulf and the Gulf of Carpentaria, showed that it is an opportunistic predator with an ontogenetic progression in its diet from microcrustacea to macrocrustacea to fish (Davis 1985b). Fish were first observed in the diet of barramundi 11–20 mm TL, being then a small numerical component of the diet (0.8%), but increasing to 87% in barramundi longer than 1000 mm TL. The piscivorous nature of barramundi makes it unsuitable for polyculture, and even in monoculture, stringent size grading would be necessary, as they are capable of eating prey barramundi up to half their own size. Cannibalism was common in Van Diemen Gulf, where barramundi comprised 11.4% of the fish species consumed, but was rarely observed in the Gulf of Carpentaria. This presumably reflects prey availability rather than food preference.

The observed transition from a diet of macrocrustacea (mainly Penaeidae and Palaemonidae) to fish (mainly Engraulidae and Mugilidae) entails spending more time feeding on pelagic species in mid-water or on the surface than on bottom-dwelling forms. This would result in greater exposure to predation and cannibalism, a factor of decreasing importance with increasing size. These dietary changes with size may be a consequence of predation avoidance rather than a preference of one type of food over another.

Migration Patterns

About 4000 barramundi were tagged in Van Diemen Gulf rivers in 1977–78 to obtain growth data and validate ageing by scale reading (Davis and Kirkwood 1984), and to determine migration patterns and

estimates of fishing mortality (Davis 1986 in press). The tagging procedure has been described by Davis and Reid (1982).

In all rivers there was a general movement of fish seawards, into the commercial fishing areas, where tagged fish were caught by commercial fishermen. Most recaptures by recreational fishermen and ourselves were at the site of tagging. Most tagging sites were downstream of the areas most popular with recreational fishermen; if tagged fish had dispersed equally upstream and downstream, there should have been many more returns by recreational fishermen. The low number of returns by recreational fishermen suggested a net movement of fish towards the coastal commercial gillnet fishery. This movement was progressive, with fish further inland taking longer to reach the coast (Davis in press, Table 1). This catadromous migration consisted mainly of barramundi which, as juveniles, had colonised inland waters accessible from the sea and, on maturity, migrated late in the wet season to spawning areas (Davis 1985a). Many of these fish were subsequently captured in coastal waters outside the spawning season, which suggests that they remained in tidal waters after spawning. This is in contrast to Papua New Guinea fish which were released in inland waters and caught at sea only during the spawning season; they presumably returned inland shortly after spawning (Moore and Reynolds 1982). Most of the mature barramundi in north Australia (particularly large females) are resident in tidal water throughout the year. Since they spawn before local salinities are lowered by the wet season floods, they do not have to make a catadromous migration to spawning grounds (Davis 1985a).

Some exchange of barramundi between river systems was recorded (Davis in press). The East Alligator River and Murgenella Creek were considered as one system, as fishing of the two areas overlaps. Only nine fish movements between river systems were observed. The significance of these movements in respect to stock heterogeneity is hard to determine. The low commercial fishing pressure in the West Alligator River (Davis in press, Table 1) probably resulted in the relatively high recovery in other rivers of fish tagged in the West Alligator River (16.7% of recaptures). Conversely, the more intensive fishing pressure in the East Alligator and Mary rivers probably reduced the numbers of tagged fish that were able to move out of these systems.

Fishing Mortality

The length of tagged fish and the percentage that were recaptured by commercial fishermen showed a positive relationship. This was largely due to fishermen using gillnets that selectively caught fish larger than the minimum legal catch length of 580 mm TL. In addition, fish may not have moved into tidal areas of the commercial fishery until they matured. Thus the high natural mortality of younger fish, coupled with the delay in their recruitment to the fishery, would result in lower returns.

Annual mortality estimates were determined by the linear method of Gulland (1969) after the number of tag returns was adjusted to take into account previously determined tag-shedding rates (Davis and Reid 1982). Fishing mortality was the only component of mortality in Gulland's model that was attributable to a single cause, and the one in which the assumptions of the model could be more or less satisfied. Estimates of fishing mortality for the Mary and East Alligator rivers pooled by age groups (age 3, $F=0.11$, s.e. $=0.03$; age 4, $F=0.20$, s.e. $=0.05$; and age 5, $F=0.24$, s.e. $=0.06$) suggested that fishing mortality increased with age. This was as expected, given the selective nature of the gillnet fishery and the likelihood of older, more mature fish moving earlier into the fishing areas.

When the analysis was restricted to legal-sized fish in specific localities, the highest fishing mortality was recorded in tidal Sampan Creek ($F=0.45$, s.e. $=0.32$) and the lowest in Shady Camp Billabong ($F=0.15$, s.e. $=0.03$), with tidal Magela Creek intermediate ($F=0.26$, s.e. $=0.08$). Annual fishing mortality estimated by Reynolds (1978) for the commercially fished population of barramundi in Papua New Guinea falls within this range ($F=0.29$). Fish in Sampan Creek were released either in the commercial fishing area or had year-round access to it, whereas fish tagged in Shady Camp Billabong had access to the commercial fishing areas only during the wet season. It is unlikely that the lower apparent commercial fishing mortality of fish released in Shady Camp Billabong was due to added fishing mortality by recreational fishermen, as releases were downstream of the main recreational fishing areas. It is more likely that the lower mortality reflects their gradual net seawards migration into the commercial fishing areas, the natural mortality incurred before reaching the commercial grounds, and any losses caused by dispersal further inland. The tendency for fishing mortality to increase with proximity to the commercial fishing grounds would then suggest that fishing mortality of barramundi resident on the mudflats of Chambers Bay (the focus of commercial fishing in the Mary River) is probably higher than the value of 0.45 estimated for fish tagged in tidal Sampan Creek. These high levels of fishing are sustained by the continual recruitment of fish from billabongs and upstream areas into the commercial fishing areas. The net seaward movement of fish and the fact that tagging was mainly conducted downstream of the recreational fishing areas resulted in low returns by recreational fishermen in this study. However, Griffin (1979) found that the recreational catch is 30% of the commercial catch, which would

suggest that fishing mortality caused by recreational fishermen is quite high further upstream.

Summary

The biology of barramundi is extremely complex. This highly successful species dominates many tropical rivers of north Australia; its success can be attributed to its dynamic and flexible biology. The sexuality of the species appears to be expressed differently in the different areas. Most barramundi are protandrous hermaphrodites, whereas those from the Songkhla Lakes in Thailand are apparently gonochoristic. The size at first maturity in males and the size at which sex change occurs varies markedly between populations studied in north Australia, with the most unusual being the sexually precocious barramundi occurring in the northeast Gulf of Carpentaria. Growth is also highly variable among individuals, rivers and seasons. Barramundi are powerful and vigorous predators taking full advantage of available resources. The migration patterns of barramundi differ markedly between north Australian rivers and those in Papua New Guinea. These differences are largely related to spawning requirements and the different environmental factors to which the species appears to have adapted so successfully. The juveniles also utilise a variety of different nursery habitats, depending on their availability in different areas. While this high degree of adaptability and vigour in the biology of barramundi has enabled it to be the dominant species in many tropical river systems, it complicates both the understanding and management of wildstock populations.

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Stock Structure of Australian and Papua New Guinean Barramundi *(Lates calcarifer)*

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INTEREST in the population stucture of barramundi was stimulated by the perceived decline in both landings and catch per unit effort (CPUE) after the peak 1977–78 catch of over 1600 t liveweight. A broad-based biological study of barramundi was initiated in 1978 on the part of the CSIRO and the state fisheries departments in both Queensland and the Northern Territory. The Fish Population Genetics Group in Cleveland began assessing the extent of electrophoretically detectable genetic variation in barramundi in late 1981. Although levels of variation were low relative to other fishes, sufficient polymorphic loci for population studies were detected. Subsequently, large-scale collecting of tissue was established through both Queensland and NT state fisheries departments and by direct contact with cooperative commercial fishermen.

Over 4500 samples have been collected since our program commenced, covering 32 locations and about 7000 km of coastline. In this report we present the results and their implications for WA and NT collections, the tip of Cape York and two PNG locations. Details of the nature of the genetic variation have been reported elsewhere (Shaklee and Salini 1985). The Cape York samples form part of a separate paper on barramundi stock structure in Queensland (Shaklee and Salini, in prep.), but have been included here to compare the closest Australian location to the PNG samples.

Genetically discrete stocks are ones where there is no normal mixing between them by way of either migrating adults which interbreed or by exchange of juveniles and/or long-lived larvae; that is a self-reproducing unit. This stock concept is the cornerstone of sound management policies for the maintenance of a fishery resource. In the case of Australian barramundi, the question of concern should be: Do we manage the fishery on the basis of a single unit stock across its entire geographic range or as a resource composed of multiple stocks? At present, the first strategy has been the basis for fishery management with only minor differences between the NT and Queensland approaches.

The essence of the existing controls concerns protecting the spawning adults from gill-netting and in addition there is a series of controls on fishing gear to minimise the removal of females (size of capture) and on numbers of commercial fishermen operating. This last control has been pursued with some success by both states to reduce the fishing effort. The other scenario of multiple barramundi stocks would obviously require a different emphasis in that each individual stock would have to be protected from overfishing because of the lack of substantial recruitment from other populations. In this case, recovery from a severely overfished situation would be a protracted event.

Tagging studies on barramundi in Van Diemen Gulf revealed considerable within-river movement of barramundi (Davis 1986). There was some evidence of limited movements between nearby rivers, less than 50 km apart, but essentially little or no coastal migrations were observed. Similar results have been obtained from tagged barramundi in Queensland waters (Garrett, pers. comm.) and in the Daly River (White, pers. comm.). Given these tagging results and the lack of definitive information on barramundi stocks, we planned to sample as many locations as possible over most of their geographic range. The aim of our population genetic approach was to determine: (1) if there are genetically discrete stocks of barramundi; and if so (2) how many stocks can be identified; (3) where are the boundaries of such stocks; and (4) if the genetic data (allele frequencies) are stable temporally.

Materials and Methods

Samples used for this part of the study were collected from Western Australia, the Northern Territory, Queensland (Cape York) and Papua New Guinea. These locations were: WA, the Ord River; NT, the Daly, Finniss, Mary, Glyde, Roper and McArthur

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rivers and Blue Mud Bay, Cape York, Pennefather, Ducie, Dulhunty, Jackson, MacDonald, Doughboy, and Cotterell rivers and Janie Creek on the west or Gulf side of the Cape, and Escape and Lockhart rivers and Orford, Shelburne and Temple bays on the eastern cape; PNG, Toro Passage at the south western mouth of the Fly River and an unnamed stream 100 km northwest of the Fly River. For the sake of statistically valid sample sizes in the genetic analyses, several small collections had to be pooled on a geographic basis. This pooling was only necessary for the Cape York collections and consisted of two separate locations on the Gulf side, Cotterell River area, Port Musgrave area, and five locations on the eastern Cape. From north to south these eastern cape locations were, I2 (Escape River), I4 (Orford Bay), (Shelbourne Bay), I6 (Temple Bay) and I3 (Lockhart River). Electrophoretic techniques have been described in detail together with explanations of the statistical analyses (Shaklee and Salini 1985, Salini and Shaklee in prep.). Validation of the electrophoretic interpretation has been discussed at length for our results (Shaklee and Salini 1985). For the purposes of this paper, results of the contingency chi square tables testing the homogeneity of alleles is the principal concern and these analyses were all computed using the BIOSYS-1 genetics program of Swofford and Selander (1981).

The null hypothesis for this analysis is that the samples being tested are drawn from the one gene pool, that is, from the one stock. A significant difference implies that the samples are from different gene pools or stocks. This analysis is carried out for each polymorphic locus and over all polymorphic loci.

Results

WA–NT Samples

The Daly and Finniss rivers were sampled five times and twice respectively to test for genetic stability over time and to test geographically close streams for stock discreteness. The samples within the Daly and from within the Finniss rivers were not genetically different and the pooled Daly River and pooled Finniss River collections were not significantly different at any of the polymorphic loci either. This implies that for geographically close rivers, in this case separated by about 50 km, the barramundi populations can be considered to be uniform or of the same stock. In addition, these samples were obtained over 14 months (Table 1) which demonstrates the stability of the genetic data over time. Most of the other locations sampled were barramundi fishing centres with at least one or more streams (capable of sustaining barramundi populations) between them. In general, the size and hence age of the barramundi used reflected the commercial sampling

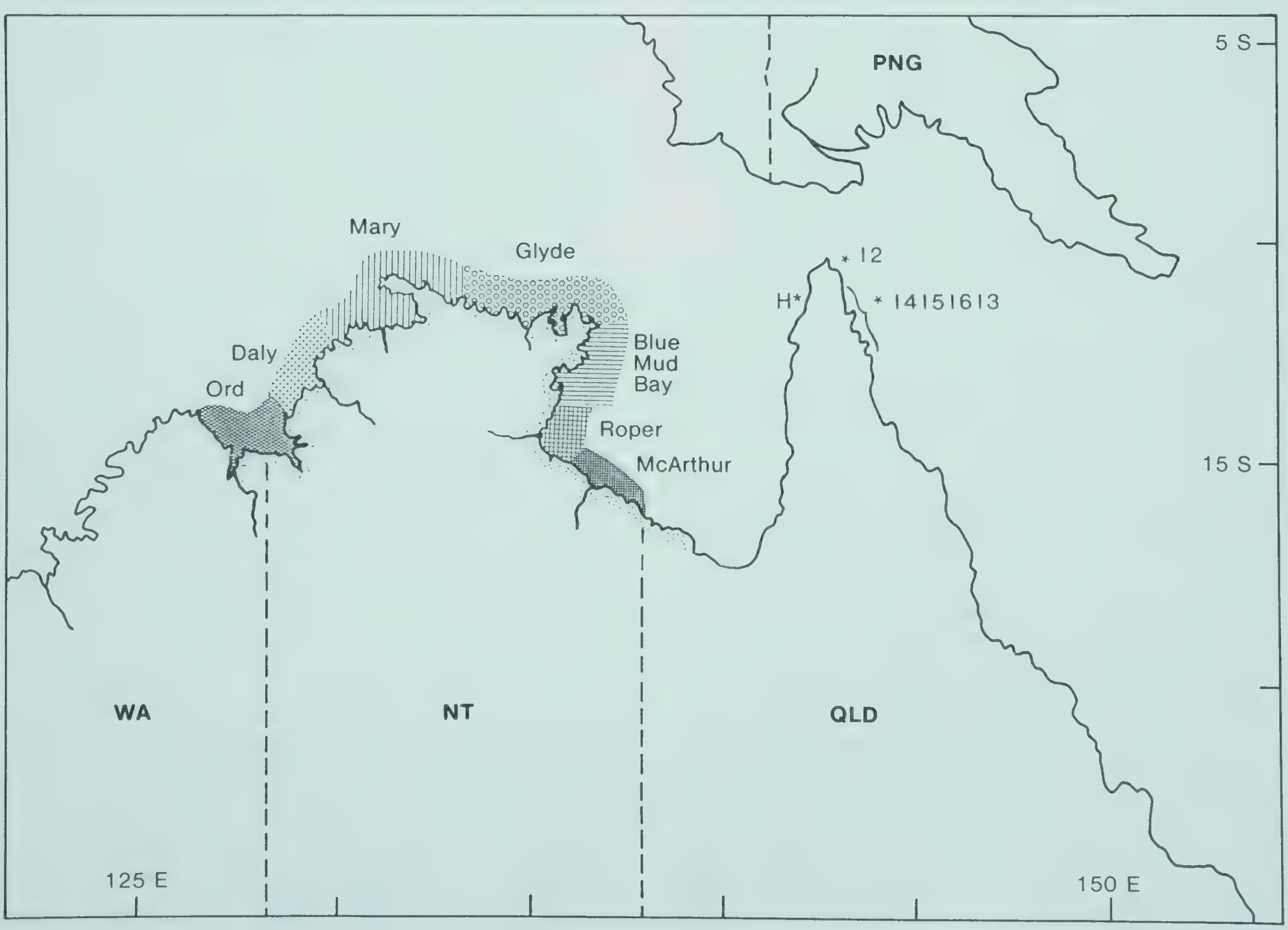

Fig. 1. Genetically discrete stocks in northern Australia and PNG. Other collections from SE Gulf of Carpentaria and the east coast of Queensland are not included.

with most fish conforming to the legal size for netting and with males predominating in the commercial catch samples.

When all seven localities were compared as if they were one population, they were strongly heterogeneous with $\chi^2 = 612$ with 54 degrees of freedom and seven loci out of the 11 polymorphic loci showing significant deviations from expectations for a single homogeneous population. To determine where the genetically discrete stocks occurred within our sample locations, each adjacent pair of rivers was statistically tested for genetic homogeneity by contingency chi square tables. The results were highly significant for each of the comparisons, that is Ord vs Daly area (Daly plus Finniss samples), Daly area vs Mary, Mary vs Glyde, Glyde vs Blue Mud Bay, Blue Mud Bay vs Roper and Roper vs McArthur indicating strong barriers to gene flow between each of the seven locations. Thus, for the WA–NT samples, there are genetically discrete stocks represented by the Ord, Daly (including Finniss), Mary and Glyde Rivers, Blue Mud Bay, the Roper and MacArthur Rivers represented by the different shading in Fig. 1.

Cape York and PNG samples

The western Cape samples comparison of area H1H2H3 (Port Musgrave) and "Cotterell River" area revealed no significant differences for all loci. This means all these collections can be considered one stock. On the eastern Cape, all five locations represented by Escape River (I2), Orford Bay (I4), Shelburne Bay (I5), Temple Bay (I6) and Lockhart River (I3) revealed genetically discrete stocks for the Escape River and a pooled area incorporating locations I4, I5, I6 and I3.

Similarly, two PNG samples represented a single population such that our samples over northern Cape York represented three genetic stocks each of which was distinct from the PNG stock. That is, there is little chance of significant genetic exchange between Australian and PNG barramundi.

If geographic separation between populations of barramundi is the major determinant of whether there are discrete stocks or not, then the Escape River and PNG barramundi populations appear to be within the range for uniform populations, given the distance between NT stocks of at least 150 km. However, despite their apparent geographic proximity at their nearest points, the Torres Straits constitute a major geographic barrier for what is essentially a shallow-water, coastal species. The WA–NT samples contained individual river collections, unlike the Cape York samples which consisted of several small collections from different streams which required grouping for analysis. Hence, the WA–NT samples provide a better indicator of the approximate coastal distances involved in the formation of genetically discrete stocks. There is no genetic distinction between the Daly and Finniss rivers separated by about 50 km, but the nearest genetically distinguishable stocks are separated by 150 km (approximately), e.g. Blue Mud Bay, Roper and MacArthur rivers.

Discussion

The primary goal of our biochemical genetics approach to studying barramundi stock structure was to attempt to provide the relevant fishery managers with previously unobtainable information. Until now, the main source of stock structure information on barramundi was provided by tagging programs, which revealed the nature and extent of fish movements within and outside their natal rivers. Davis (1986) carried out a comprehensive tagging program on Australian barramundi in Van Diemen Gulf, Northern Territory. His results confirmed the downstream spawning movement prior to and during the wet season, together with a small amount of movement between streams less than 50 km apart. Similar movements have been observed for barramundi tagged in the Daly River (White, pers. comm.) and on the east coast of Queensland (Garrett, pers. comm.). The genetic data we have gathered complements all the available tagging data and is especially useful as a research technique when covering such a wide geographic range. To attempt a tagging program on such a scale would have been impossible with the same resources. It should be noted that, given sufficient levels of detectable genetic variations, the life history of the barramundi lends itself to the biochemical genetics approach. Lack of long range migrations, a short planktonic larval stage and a dependence on coastal nursery habitats adjacent to spawning sites for larval and juvenile barramundi (Davis 1985; Russell and Garrett 1983, 1985) provide the basis for establishing barriers to gene flow. This life history results in genetically distinct populations through random genetic drift. In contrast to the observed Australian tendency to form identifiable localised populations, Moore and Reynolds (1982) and Moore (1982) were able to document significant coastal migrations by Papua New Guinea barramundi originating from within the Gulf of Papua and its streams.

This behaviour enhances the mixing of genes and so there is less chance of localised populations forming and becoming genetically distinct from one another. More important than the description of these stocks is their implications for the management of the commercial (and amateur) fishery and, in the near future, the control of hatchery brood stock and fingerlings. As far as the commercial fishery is concerned, it should be clear that it would be biologically more appropriate to manage the fishery as a multiple stock fishery rather than the present modus operandi which acknowledges the unit or single-stock strategy. Because we have a

multiple stock situation with documented short distance movements, then this biological information must be taken into account with regard to the location of habitat reserves. The obvious diversity of stocks throughout their range, evident from our work, requires barramundi reserves to be located in such a way that they can feasibly contribute to and, in times of resource depletion, replenish commercially fished stocks.

With the very real prospect of barramundi hatcheries supplying fingerlings for restocking purposes, the consequences of uncontrolled mixing of different genetic stocks must be addressed. Biologically, the danger in releasing fingerlings derived from brood stock which were not indigenous to the release site is the loss of genetic discreteness for the mixed stocks. The genetic data we have collected indicates that only a few fish moving between stocks per generation is sufficient to eliminate their genetic discreteness. It follows from hatchery experience in North America and Europe with salmon and trout species that it is essential to regularly obtain new genetic stock from the wild to minimise the loss of desirable genetic traits as a result of inbreeding depression (Aulstad and Kittelsen 1972; Shaklee 1983; Vuorinen 1984; Hynes et al. 1981). At the 1980 Stock Concept Symposium in Ontario, Maclean and Evans (1981) cite examples of reduced viability attributed to direct mixing of stocks or via hatchery releases. To minimise such risks Krueger et al. (1981) recommended that, where there is a likelihood of gene flow between stocked fish (hatchery releases) and the local wild population, the broodstock should be taken from environmentally similar locations. Again the intention is to maintain genetically discrete stocks. It is generally recognised that genetically discrete stocks represent the best adapted genotypes for that particular area and as such constitute a valuable component of the species' genetic variability (Shaklee 1983; Thorpe et al. 1981; MacLean and Evans 1981). Because of the high public profile and economic value of the barramundi fishery, commercial and recreational, it would be prudent to choose the least risk of resource deterioration in considering future developments. In conclusion, we endorse the three recommendations to fishery management from the 1980 Stock Concept Symposium (Spangler et al. 1981):

1. "That research be intensified to resolve further the existence of genetic and environmental stocks and mechanisms underlying their maintenance or persistence in wild populations. This research should include intensive studies of gene flow within and between stocks to determine the risks associated with the extirpation of discrete stocks.
2. "That fishery agencies concerned with the rehabilitation of self-producing stocks re-examine fish culture practices in the light of the stock concept according to the specific concerns raised by Hynes et al. (1981), and that hatchery stocks designated for release in wild environments be carefully evaluated with respect to their potential genetic impact on extant populations.
3. "That fishery regulatory mechanisms be developed so as to protect exploited species from selective exploitation of stocks exhibiting the extremes of vital life history characteristics, such as sexual dimorphisms, early or late spawning, size, and growth."

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Barramundi/Sea Bass *(Lates calcarifer)* Research in Australia

R.K. Griffin*

DESPITE its popularity as a food item and its legendary prowess as a game fish, research into the biology of barramundi *(Lates calcarifer)* was minimal until the late 1970s. By that time the demand on the resource by both commercial and recreational interests, particularly in the Northern Territory and Queensland, had reached the point where significant reduction of stocks, at least in some areas, was causing considerable concern.

In fact it was concern that stocks were being overfished which led to the earliest reported research project on barramundi in Australia. The Queensland Government, in 1954, commissioned the CSIRO Division of Fisheries and Oceanography to investigate the biology of the species. The work was conducted and reported by Dunstan (1959). He studied most of the basic biology, reporting on factors affecting distribution, reproduction, feeding, age and growth. He also reported details of the commercial fishery and factors which affected catch. Tagging results were disappointing with over 2000 being tagged and only 16 recaptured. This work, however, presented a fairly complete and accurate picture of the biology of barramundi and remained the major reference on the subject for almost 20 years.

Recent studies have confirmed the accuracy of Dunstan's conclusions except in the areas of growth and reproductive biology. Dunstan's preliminary growth estimates (a promised later paper on the subject did not materialise) have been found by later workers to be too high. Despite Dunstan's conclusive evidence that maturation and spawning occurred only in salt or brackish tidal waters, the myth persisted in Australia until quite recently that barramundi spawned in fresh water. Dunstan did not conclude that barramundi was protandrous and this fact did not become known until the work of Moore and Reynolds in Papua New Guinea 20 years later (Moore 1979; Moore and Reynolds 1982; Moore 1982; Reynolds and Moore 1982).

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Distribution

Dunstan assessed the distribution in relation to river geography and concluded that the larger, slower-flowing rivers have a much greater abundance of barramundi than the shorter, more swiftly flowing rivers. Significant differences in distribution of fish within rivers on a seasonal basis were also pointed out with immature fish preferring fresh water and mature fish the brackish water. A spring (or late dry season) movement of mature fish from brackish tidal waters to coastal spawning areas was also defined.

Western Australia Fishery

The next published work on barramundi in Australia was by Morrissy (1969). This brief investigation was carried out by the Western Australian government in response to two main factors. The first was concern about the impact of river impoundments, in particular the Ord River Dam, on barramundi, and the second related to emerging conflicts between recreational anglers and commercial gillnetters in some areas. This era of barramundi research in Western Australia appears to have been fairly short-lived as no further significant contributions to the literature appeared until very recently. Since that time the extent of barramundi work has been largely maintaining a watching brief over a small-scale commercial fishery. The problems of access upstream of barriers on rivers in the northwest part of Western Australia appears to have been put aside as an insoluble problem at this stage.

Interest in barramundi has been revived quite recently, particularly in regard to aquaculture. In 1985, Morrissy reported on the status of the barramundi, and a new research program is being implemented.

Northern Territory Fishery

In the Northern Territory, management of the barramundi fishery, as it developed in the 1960s and early 1970s, was based to a considerable degree on the findings of Dunstan's work in Queensland and his later work in Papua New Guinea (Dunstan 1962).

The first research in the Northern Territory on barramundi was conducted in 1973 and 1974. Sam-

pling and tagging of barramundi was undertaken in the Mary River, east of Darwin. This work was largely of an exploratory nature and was discontinued because of staff shortages and altered priorities. No significant results were achieved.

By 1978, however, falling catch rates in the, by now, well-developed commercial and recreational fisheries for barramundi were causing concern. An economic assessment of the fishery carried out in 1974–75 (Copes, unpublished reports) recommended a reduction of the number of commercial operators to improve economic returns.

In 1978–79 the status of the fishery was reviewed (Grey and Griffin 1979). Estimates of sustainable yield using the Schaefer surplus production model suggested that effort levels were too high, and management measures designed to reduce effort and optimise yield were introduced.

Recreational Fishery

During 1978–79 a series of roadside surveys of recreational fishing in the Arnhem Highway area from the Adelaide River to the East Alligator River was conducted (Griffin 1982). The aim of those surveys was to estimate the significance of recreational catch and effort. Those surveys suggested that the annual recreational catch for the Arnhem highway area was in excess of 80 t. This catch represented approximately 23% of the combined commercial and recreational catch for the survey area for 1978–79.

Current Research

From 1980 through to the present, research on barramundi in the Northern Territory has concentrated mainly on monitoring of the commercial fishery and assessment of the biological factors affecting management.

Such factors as seasonal variation in catches, seasonal movement, mesh selectivity, spawning and recruitment are being investigated. Seasonal movements of barramundi (Griffin, in prep.) and differences in distribution within rivers were found to be very similar to those observed by Dunstan (1959).

Variations of catch associated with the pattern and amount of rainfall have been found with catch rates being higher in years of high rainfall. A likely association of abundance of 0+ fish with early wet season rainfall (i.e. before February) has also been investigated (Griffin 1985).

In 1978 a joint program of research involving the Northern Territory, CSIRO and Queensland research organisations was commenced. The CSIRO research was conducted in the Van Diemen Gulf area of the Northern Territory and in its later stages in the eastern Gulf of Carpentaria. This program, under the charge of Dr Tim Davis, has produced extensive published results in the areas of growth, reproduction and movements (Davis 1982, 1984a,b, 1985; Davis and Kirkwood 1984). Attempts to provide estimates of relevant management parameters have been confounded by the complex life cycle of the species and the nature of the fishery, further complicating any management initiatives.

The CSIRO program was completed in 1982 and analysis of results is almost complete. Davis's paper (these proceedings) provides results of this work.

Research in Queensland has proceeded along much the same lines as that in the Northern Territory. A team of two scientists and two assistants conducted extensive sampling of the barramundi population on the east coast of Queensland from a base in Cairns between 1978 and 1981. The earlier part of the program concentrated on distribution movements and growth with over 3000 fish being tagged and 438 recaptured. Patterns of growth and movement were found to agree substantially with those reported elsewhere. Russell and Garrett, in a 1982 report to the Fishing Industry Research Committee presented some results of that research. Other results describing behaviour of early life history stages are presented in Russell and Garrett (1983, 1984).

Since that time research has been expanded into investigations of the fishery, both on the east coast and in the Gulf of Carpentaria. Management strategies based on that work have been developed and are reported elsewhere in these proceedings.

In the past 2 years research effort in Queensland has largely shifted toward culture of barramundi. Sampling has been concentrated on locating spawning areas and defining spawning cycles, and developing techniques appropriate to culture of barramundi in Queensland. The need for ongoing research into this most complex species is now recognised, and work is being undertaken throughout its range in Australia to further examine the factors which affect its abundance, and its catchability by both commercial and recreational fishermen.

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Reproduction in Queensland Barramundi *(Lates calcarifer)*

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Barramundi or giant perch is a large centropomid fish widely distributed in the coastal rivers and inshore waters of northern Australia (Dunstan 1959). In Queensland, the distribution of barramundi ranges from the Noosa River in the southeast of the state (Grant 1982), northwards to Cape York Peninsula and into the Gulf of Carpentaria.

Dunstan (1959) described *L. calcarifer* in Queensland as a dioecious catadromous species that underwent a prolonged spawning season through the summer northwest monsoon period (usually October to March). More recent work by Moore (1979) in Papua New Guinea identified the species as a protandrous harmaphrodite.

Biochemical investigations by Shaklee and Salini (1983, 1985) revealed the presence of several distinct genetic types in Queensland barramundi. Davis (1984a) and Garrett (unpublished data) established that the stocks of far northern Cape York Peninsula streams grew more slowly and attained sexual maturity at an earlier age than more southerly forms.

Following Southeast Asian successes in the mass culturing and rearing of *L. calcarifer* (e.g. Ruangpanit et al. 1984, Maneewong et al. 1984), the barramundi has created widespread interest as a fish for aquacultural and fishery enhancement purposes in Queensland. Detailed information of the fish's breeding requirements is necessary to allow an accurate estimation of potential hatchery production (MacKinnon 1985).

This review summarises and attempts to interpret all the available information on wildstock reproduction in Queensland barramundi.

Seasonality of Spawning

Queensland *L. calcarifer* have a single annual spawning period that extends from October to March. However, the timing and duration of the breeding season vary between regions, river systems and from year to year (Davis 1985; Russell 1986a). Peak spawning in northern Queensland stocks occurs during November and early December (Garrett and Russell 1982; Davis 1985; Russell and Garrett 1985). More southerly east coast stocks have a late December to early January breeding peak (Russell 1986a). Dunstan (1959) established two spawning peaks (November and January) in central Queensland fish. Water temperature appears a primary factor controlling the commencement of spawning in barramundi (Davis 1985). The latitudinal trend in peak spawning period may result from tropical stocks spawning at water temperatures below the annual maxima. Further south, populations may spawn at temperatures nearer the local maxima.

Gonad development may be extremely rapid, the greatest growth taking place in the spring months prior to spawning (Dunstan 1959). Spawning begins at the onset of, or just prior to, the monsoon season (Dunstan 1959). Moore (1982) noted that the spawning of Gulf of Papua *L. calcarifer* was delayed if the wet season was delayed, and felt that the fish spawned in response to an organic stimulus released through rain.

Dunstan (1959) and Moore (1980) suggested that the extended nature of the breeding season was produced by the differential arrival of mature fish on the spawning grounds. There is confusion as to whether or not the season is further prolonged by delayed breeding of total spawners or the repeated breeding of partial spawners (Davis 1985).

The reproductive strategy of barramundi is well suited to Queensland's highly seasonal rainfall regime in which the formation of water bodies associated with monsoon rains provides an environment for growth and survival of young fish (Orr and Milward 1984). *Lates calcarifer* breeding may be synchronised so that larval and juvenile fish can exploit nursery habitats formed during the monsoon season (Davis 1985).

Location of Spawning Grounds

Barramundi spawn in saltwater environments. No adult fish with ripe gonads have been taken in non-flowing freshwater or landlocked lagoons (Dunstan 1959). Gonad development was retarded in landlocked freshwater *L. calcarifer* from the Gulf of Carpentaria (Davis 1985).

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Fish with ripe-and-running gonads have been found only in the lower estuaries of rivers and their adjacent foreshores (Garrett and Russell 1982). In northeast Queensland rivers, spawning fish were located in shallow (up to 2 m deep) side gutters near the mouth but off the main channel. These gutters are characteristically protected from the strongest run of the flood and ebb tides by adjacent sand and/or mudbanks. Aggregations of ripe-and-running male and female barramundi were just inside of and just outside of river and creek mouths in central and southern Queensland (Dunstan 1959; Russell 1986a), and around coastal mudflats near river mouths in the southern Gulf of Carpentaria (Davis 1985).

Spawning can take place well upstream in rivers as long as salinities are high (approximately 30‰, Davis 1985). The catadromous migration of adults to specific spawning grounds, presumably because of inadequate local salinities (as occurs in Papua New Guinea; Moore 1980, 1982), does not necessarily happen in Queensland rivers. Garrett and Russell (1982) found localised spawnings in northeast Queensland, where the rivers have relatively low freshwater discharges. Local spawning of barramundi in rivers rather than on communal spawning grounds is consistent with recent genetic evidence of stock heterogeneity (Shaklee and Salini 1985).

Spawning grounds appear to be located close to larval and juvenile habitats, or lie within the path of currents that transport the larvae to such habitats (Garrett and Russell 1982). The positions of spawning grounds probably differ slightly from year to year depending on coastal salinities (Moore 1982). These in turn vary with the degree of river discharge.

Conditions for Spawning

Detailed analyses of the environmental conditions necessary for spawning in Queensland barramundi have not been published, but water temperature and salinity appear to be controlling factors (Moore 1980; Davis 1985). MacKinnon et al. (in preparation) found barramundi spawned in a northern Gulf of Carpentaria estuary when water temperatures ranged from 27‰ to 33°C and salinities from 28 to 34‰. Salinities in the range necessary for barramundi egg fertilisation (in Thailand 28–32‰, Maneewongsa and Tattanon 1982) occur in the shallows near the mouths of most rivers in northern Australia during the first months of the spawning season (Davis 1985).

In Thailand, barramundi spawning has been linked to the lunar cycle (Kungvankij et al. 1984; Sirimontaporn et al. 1984). Egg release occurred just after the turn to the flooding evening tides of new and full-moon periods. In Papua New Guinea, Dunstan (1962) found a ripe-and-running female during the full moon period. MacKinnon et al. (in preparation) caught spawning barramundi in a northern Gulf of Carpentaria estuary only in the evenings of the week following both new moon and full moon.

Barramundi appear to be surface spawners (Moore 1980), so local weather conditions may exert short-term effects on the intensity of local spawning activity (MacKinnon 1985). Coastal spawning grounds are usually close to the supralittoral nursery habitat of larvae and juvenile fish (Garrett and Russell 1982). Moore (1980) suggested that an organic compound (a petrichor, see Lake 1967) was released from nursery swamps newly inundated by spring tides or monsoon rains, and this stimulated nearby adult fish to spawn. He did not conduct any experimental tests of this hypothesis.

Spawning Strategies

Barramundi display three different strategies that maximise spawning success. Firstly, male fish appear to outnumber the females participating in the breeding event. Russell (1986a) noted a greater proportion of male fish on Queensland east coast spawning grounds, as did MacKinnon et al. (in preparation) in northern Gulf of Carpentaria estuaries. Several males probably fertilise the eggs of a single female barramundi (Moore 1980), ensuring the successful fertilisation of all eggs released.

Secondly, barramundi spawn mainly at the beginning of the incoming tide (MacKinnon et al., in preparation). This enables the maximum passive penetrations of larvae by currents into the upper tidal areas (Davis 1985) where nursery grounds are found.

Thirdly, dusk or evening spawning may be important in protecting barramundi pelagic eggs from predation (Holt et al. 1985). Lowe-McConnell (1969) stated that high fecundity and a synchronised spawning effort, characteristics displayed by barramundi, are effective mechanisms for 'predator swamping.' Predation on the barramundi themselves, even when aggregated for spawning, is probably rare as they are larger than most other piscivorous predators of the estuarine and nearshore environment.

Frequency of Spawning

Most early accounts of barramundi breeding in Queensland reported a single spawning each season. Dunstan (1959) claimed a prolonged season was due to the continuous migration of fish into the spawning area and not to an extensive spawning period for individual fish. However, Moore (1982) found that while small female Gulf of Papua barramundi were total spawners, many large female fish exhibited multiple spawning. The larger females, then, had a more protracted breeding season than the smaller, younger fish. Davis (1984b) found no evidence of multiple spawning in a histological study of ovaries from southern Gulf of Carpentaria specimens.

In Thailand, *L. calcarifer* is a multiple spawner

(Barlow 1981; Kungvankij et al. 1984; MacKinnon 1985), and typically there is a major and a minor period of spawning activity each month during the breeding season. MacKinnon et al. (in preparation) established biweekly lunar-related spawnings in the Embley and Hey rivers, northern Gulf of Carpentaria. They also found partially spent female fish, evidence of multiple spawning, in the Embley and Hey river populations.

From the presence of both mature and immature barramundi of the same size range in central Queensland coastal catches, Dunstan (1959) concluded that not all *L. calcarifer* spawned each year. Most of the 650–850 mm fish he examined during the spawning season showed no sign of gonad development.

There is no suggestion in the published literature that Queensland barramundi stop breeding after a certain age or size. Moore (1980) quoted Thai findings which concluded that ovaries of very large *L. calcarifer* in that country contained fibrous tissue and had few or no eggs. Larger Queensland specimens produce more eggs per unit of body weight than smaller fish (Dunstan 1959; Davis 1984b; Russell 1986a).

Spawning Movements

Catadromous movements associated with breeding in Queensland barramundi were reported by Dunstan (1959), Garrett and Russell (1982), and Russell (1986a). Dunstan (1959) detected a spring downriver migration to coastal waters of maturing central Queensland fish, usually in pairs. During the wet season months, these barramundi moved in small schools along the coast to spawn away from the effect of flood waters in estuaries and adjacent bays (Dunstan 1959). Neither Garrett and Russell (1982) nor Davis (1985) found evidence of coastal migrations to specific spawning grounds in northeast Queensland and the southern Gulf of Carpentaria respectively.

Factors that stimulate the annual catadromous movements of mature Australian barramundi have not been studied. In Papua New Guinea, falling water levels in freshwater habitats may initiate the movements (Moore and Reynolds 1982). Falling water levels induce mature fish to migrate from swamps into deeper rivers and lakes, and from there to the coastal waters where the high salinities required for egg fertilisation and hatching success occur.

Shortly after spawning, Papua New Guinea barramundi move to inland waters (Moore and Reynolds 1982). However, in Queensland, barramundi tagged in inland waters have been recaptured in coastal waters long after the spawning season (Garrett and Russell 1982), and Dunstan (1959) found that spent fish remained in coastal areas for long periods. These results suggest the post-spawning behaviour of barramundi is variable.

Sex Change

Moore (1979) identified the Papua New Guinea barramundi as a protandrous hermaphrodite. The wide occurrence of protandry in Queensland stocks was confirmed by Davis (1982, 1984a) for the Gulf of Carpentaria, by Garrett and Russell (1982) for the northeast coast, and by Russell (1986a) for the central and southeastern coast. The gonads of barramundi are strongly dimorphic, and a complete reorganisation of gonad structure and function occurs with sex inversion (Moore 1979), probably under the influence of hormones (Davis 1982).

Male barramundi spawn at least once and sometimes for a number of years before changing sex (Moore 1980; Davis 1984a). Sex reversal is initiated as the male testes ripen for the last time, and the transition to ovary is completed within about a month of spawning (Davis 1984a). Unlike the Papua New Guinea situation (Moore and Reynolds 1982), inversion in Queensland fish occurs in tidal waters.

Sex inversion normally occurs when male fish are about seven years old and 820 mm long (Davis 1982, 1984a), but is more likely to be related to age rather than size. Inversion eventuates much earlier in the males of the stunted precocious stocks that inhabit streams in far northern Cape York Peninsula (Davis 1984a, Garrett, unpublished data).

Primary females which are not derived from male fish also occur in barramundi populations (Moore 1980). It is also possible that some male barramundi may not undergo sex inversion (Garrett and Russell 1982). A very small number of synchronous hermaphrodites have been found in Gulf of Carpentaria barramundi populations (Davis 1982, Garrett unpublished data).

Fecundity

The fecundity of Queensland barramundi is one of the highest reported in the teleost literature. Dunstan (1959) estimated the average fecundity of central coast barramundi at 0.6×10^6 eggs/kg of body weight. Russell (1986a) obtained similar figures for barramundi in other east coast areas. Davis (1984b) derived much higher fecundity estimates for Gulf of Carpentaria fish. A 1240 mm specimen yielded 46×10^6 eggs (approximately 2.3×10^6 eggs/kg of body weight). He found no significant differences in fecundity between female barramundi from the southern Gulf region and similar-sized specimens from sexually precocious stocks further north. Barramundi from northern Queensland waters appear more fecund than those of more southern latitudes.

Patnaik and Jena (1976) and Kungvankij et al. (1984) indicated that fecundity in barramundi was related to the size and weight of the fish. A curvilinear expression best defines the relationship between fecun-

dity and weight in Australian fish from the Northern Territory and Gulf of Carpentaria (Davis 1984b).

The fecundity estimates of Dunstan (1959), Davis (1984), and Russell (1986a) probably represent the total annual production of eggs for the individual fish sampled. The lower fecundities derived for Gulf of Papua fish (Moore 1980) may be a consequence of multiple spawning in the large females (Moore 1982), some eggs having been released prior to ovary examination (Davis 1984b). The greater variability in fecundity estimates for larger fish compared with smaller individuals in Queensland barramundi (Davis 1984b; Russell 1986a) may also be evidence of multiple spawning in these stocks.

Size at Sexual Maturity

Typically, Queensland barramundi attain sexual maturity (as males) in their third to fifth year of life. The smallest sexually active male fish in northeast Queensland stocks was 535 mm long (Garrett and Russell 1982). Davis (1982) established the length at sexual maturity for southern Gulf of Carpentaria fish as 550 mm. Russell (1986a) reported a length of 545 mm in central and southern east coast stocks.

Precocious male barramundi in far northern Cape York Peninsula populations mature in their first or second year of life at body lengths around 250 mm (Davis 1984a; Garrett unpublished data). The stunted growth of fish in these stocks was probably the effect of sexual precocity (Davis 1984a).

Because *L. calcarifer* is a protandrous hermaphrodite, there are few small females in a population. Coulter (1953) and Whitley (1959) reported that female barramundi in Queensland matured when approximately 840 mm in length. In his central Queensland coast captures, Dunstan (1959) found the smallest female fish with well-developed gonads was 760 mm long. He recognised later (Dunstan 1962) that female barramundi became mature at a larger size than did males. As females, barramundi may not commence egg production until they are quite old (e.g. 8 years old, Davis 1984a).

Both Moore (1980) and Davis (1984b) suggested that the high fecundity observed in *L. calcarifer* compensated for the female's low representation in barramundi populations and the late onset of their reproductive function. Adequate recruitment to local populations may be maintained by only small numbers of large female fish.

Development of Eggs and Larvae

Dunstan (1959) and Russell (1986a) reported that Queensland *L. calcarifer* was a broadcast spawner of pelagic eggs. Fertilised barramundi eggs were each 0.7 mm in diameter, possessed a single oil globule of 0.2 mm diameter, and hatched out a 1.5–mm larva after an incubation time of 17 hours at a water temperature of 28°C (MacKinnon et al., in preparation). These findings are in agreement with overseas results (Barlow 1981; Maneewong and Watanabe 1984; Maneewongsa and Tattanon 1982).

After hatching, the larvae enter supralittoral wetland swamps (Davis 1985; Russell and Garrett 1985) and tidal pools and gutters (Russell and Garrett 1983) near the spawning grounds (Garrett and Russell 1982). The almost quartermoon spawning periodicity observed by MacKinnon et al. (in preparation) in a northern Gulf of Carpentaria estuary in 1985 may help ensure that newly hatched larvae remain near the spawning grounds. Larvae can be transported passively by tidal currents well upriver (Russell and Garrett 1985), and postlarvae may enter freshwater habitats directly (Dunstan 1959).

Details of larval and postlarval development in Queensland *L. calcarifer* have not been published, but Moore (1982) provided descriptions of the immature phases of Gulf of Papua fish. The importance and use made of certain supralittoral habitats by postlarval barramundi in Queensland have been documented by Davis (1985) and Russell and Garrett (1983, 1985). These localities provide the fish with an almost predator-free and prey-rich environment that promotes survival and improves growth. However, juvenile barramundi must tolerate a wide range of salinities and water temperatures in these localities (Russell and Garrett 1983, 1985).

Constraints on Breeding Success

Recruitment into Queensland river systems depends largely on the successful spawning of local populations (Davis 1985; Shaklee and Salini 1985). Access to the spawning grounds is an essential prerequisite to successful breeding by adult fish. Numerous barrages and weirs have been constructed across coastal streams in Queensland to impound water supplies for domestic, agricultural and industrial use. Such man-made barriers interfere with the catadromous movements of *L. calcarifer* (Harris 1985). The fishways incorporated into the designs of many dams and barrages have not proved effective (Kowarsky and Ross 1981).

Nursery habitats appear critical to the life cycle of the barramundi and their destruction by urban and agricultural development could lead to a decline in local barramundi stocks (Russell and Garrett 1985). Russell (1986b) found that young barramundi were unable to make use of alternative habitats for nursery purposes when coastal wetlands were destroyed. He suggested that the observed decline in Queensland east coast barramundi fishery landings over the past three decades was due, in part at least, to the destruction of wetlands associated with coastal development projects.

Adverse local weather conditions and the timing and strength of the monsoon can disrupt local breeding

activities in *L. calcarifer* (Dunstan 1959; MacKinnon 1985). The numbers of spawning fish at sea were greatly reduced when the wet season was not pronounced and floodwaters were insufficient to release landlocked adult barramundi (Dunstan 1959). Davis (1985) argued that the seasonally late spawning of landlocked fish, when it occurred, was unlikely to result in significant recruitment during normal monsoon seasons because of heightened predation in already-occupied nursery grounds. In years of erratic monsoonal activity, barramundi juveniles from early season spawnings may perish as the nursery habitats dry out (Moore 1980). When this occurs, juveniles from late-spawning fish can occupy these same areas without risk when they are again inundated.

Moore (1980) argued that protandrous sex inversion and high fecundity in barramundi enabled the larger, more successful individuals (the female fish) to make the greatest contribution to the gene pool of a particular population. This mechanism could be disrupted by selective mortality of females through fishing exploitation, resulting in a drastic reduction in egg production and possibly a rapid decline in population numbers (Moore 1980). Excess fishing pressure may be a factor in the recent decline in Queensland east coast commercial fishery landings (Russell 1986b).

Future Research

Further research on a number of aspects of *L. calcarifer* reproduction would aid the developing barramundi aquaculture industry in Queensland and assist in the formulation of fishery management practices.

The stock depletion described by Moore (1980) that accompanies high fishing exploitation of female barramundi may not occur if the age of sex inversion is related to the abundance of female fish. As a population of *L. calcarifer* is exploited and the proportion of females is further reduced, inversion may occur at an earlier age. Monitoring the size at which different populations change sex may be a useful management tool (Davis 1982). The present data do not allow an assessment of this situation, and further research is required.

Establishing whether or not Queensland barramundi can spawn more than once during a season is necessary to allow accurate estimates of potential hatchery production. It may be possible to extend the spawning season of captive broodstock, and hence the number of hatchery production cycles per year.

Continuing urban, rural and industrial development indicate that further stream regulation will occur along the Queensland east coast. If local barramundi populations are to have access to local spawning grounds, then more effective fishways must be incorporated into the structure of stream barriers. The effect of inland stream modification and regulation on coastal spawning grounds should be considered by water authorities.

Concomitant with coastal development is pressure on wetland habitats. Russell (1986b) suggested a close positive relationship between juvenile nursery areas and barramundi catches in local fisheries. The implications of this should be further investigated. The likely consequences to nearby wetlands of development projects should receive careful consideration by appropriate authorities.

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Review of Juvenile Barramundi *(Lates calcarifer)* Wildstocks in Australia

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BARRAMUNDI *(Lates calcarifer)* inhabits coastal rivers and nearshore waters of much of the tropical Indo-West Pacific outside the African continent (Greenwood 1976). In Australia, its effective distribution around the northern coast is from about the Mary River in eastern Queensland (Dunstan 1959) to the Ashburton River in central Western Australia (Shaklee and Salini 1985). It is a major food fish throughout its range. In northern Australia, barramundi stocks support a major inshore gillnet fishery and a large angling sport fishery.

The basic biology of the species is now reasonably well documented. In Australia and Papua New Guinea over the past 15 years a number of studies were undertaken to supply biological information pertinent to the rational management of the fisheries. The early life history of *L. calcarifer* has received considerable attention both in these studies and in others overseas (e.g. Davis 1985a; De 1971; Dunstan 1959, 1962; Ghosh 1973; Kowtal 1977; Moore 1980, 1982; Moore and Reynolds 1982; Mukhopadhyay and Verghese 1978; Patnaik and Jena 1976; Russell and Garrett 1983, 1985).

This paper presents a review of major studies undertaken into juvenile barramundi wildstocks. The utilisation of coastal wetlands by juvenile barramundi and the possible consequences to local barramundi stocks of the destruction of these habitats in Queensland are also discussed.

Major Research Studies

General

A wide range of terms has been used in papers when referring to juvenile barramundi. In this review, unless otherwise specified, juvenile barramundi will refer to postlarval, young-of-the-year fish. A similar confusion exists where fish lengths have been given. It is assumed that, unless otherwise specified, all lengths described in the literature are total lengths. All lengths given in this review are total lengths.

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Juvenile Development

Detailed descriptions of the development of juvenile barramundi have been given by Moore (1980, 1982) for Papua New Guinea stocks and by Ghosh (1973) for Indian populations. A summary of these descriptions is given in Table 1. No detailed descriptions of juvenile development are available from Australia but pigmentation patterns appear very close to those described by Moore (1980, 1982) for Papua New Guinea fish (Russell and Garrett, unpublished data).

Table 1. Summary of development stages of juvenile barramundi.

7.5 mm Ghosh (1973)	Median fin fold connecting dorsal, caudal and anal fins no longer present; spines and rays clearly marked; dorsal with 8 spines and 11 rays, anal with 3 spines and 7 rays, and caudal with 23 rays; chromatophores developing along the dorsal profile and also the ventral profile.
8.4 mm Moore (1980, 1982)	Development of fins and supporting rays complete; caudal peduncle sharply demarcated; no fin fold; extensive pigmentations with three transverse bands of dense chromatophores and a scattering of black blotches on the head; dorsal and central ocelli on the caudal peduncle.
10 mm Ghosh (1973)	Similar general features to adults; elongation and depression of dorsal profile above the eye; dorsal and anal fins with a full complement of rays and spines but pectoral with only 14 rays; pre-operculum with serrated margin and four angular spines; vertical bands of chromatophores developed.
12–20 mm Moore (1980, 1982)	Scalation complete by 12 mm; elongation of head but dorsal profile straight; body pigment reabsorbed in some areas so that

(Continued)

	the dark caudal band is often subdivided and the anterior band is divided at the level of the dorsal origin; caudal ocelli distinct; more extensive pigmentation of the head.
12.5 mm Ghosh (1973)	Pre-operculum serrated with five angular spines; maxilla reaches below the hind edge of orbit; villiform teeth present on jaws, vomer and palate; ray and spine development complete in the fins; cycloid scales first appear; chromatophores developed into three distinct bands.
20–50 mm Moore (1980, 1982)	Similar structure and form to adults; pigmentation develops between transverse bands so by 50 mm the pattern is one of irregular blotching; spinous dorsal is dark as are the basal sheaths of the soft dorsal and anal fins and the anterior and basal regions of the ventral fins.
20–25 mm Ghosh (1973)	Lateral line discernible; resembles adults except for colouration; three vertical bands of chromatophores present; scales showing ctenoid features.
50–100 mm Moore (1980, 1982)	Pigmentation becomes more uniform so that much of the blotching is lost; a darkening of the centre of the scales produces a series of indistinct longtitudinal lines.
52–69 mm Ghosh (1973)	Resembles adult fish in all characters except silver colouration; vertical bands become less distinct with more extensive pigmentation.
100+ mm Moore (1980, 1982)	Dorsal head stripe the only distinct colouration.

Movements

A number of studies have covered juvenile barramundi movements in coastal waters after their departure from nursery habitats (e.g. Dunstan 1959; Reynolds and Moore 1982; Davis 1985a; Russell and Garrett, in preparation). In the Gulf of Papua, Reynolds and Moore (1982) tagged and released 893 juvenile barramundi in coastal areas with 115 later being recaptured. They determined that from March to June, during the initial movements of juvenile *L. calcarifer* into coastal waters, 21.5–23% were recaptured in the same locality. Later, from July to August, only 3.6% were recaptured in the same locality suggesting increased movement from tagging sites. Direction of movement in the Gulf of Papua was mostly easterly from July to October but there were a number of short westerly movements during November and December. Reynolds and Moore (1982) concluded that young-of-the-year fish, after leaving the nursery grounds, became dispersed throughout the Daru coastal region, and moved as far east as the Fly River by the end of their first year.

In a similar tagging study in northeastern Queensland, Russell and Garrett tagged 1268 juvenile barramundi in two tidal creeks. Their results indicated that most juvenile barramundi remained resident in the same tidal creeks until the end of their first year, when they moved out into the main estuary, dispersing to nearby estuaries and coastal habitats. In an earlier study in eastern Queensland, Dunstan (1959) observed that early juveniles moved into fresh water during the dry winter months and occasionally even penetrated into the headwaters of rivers. In the Northern Territory Davis (1985a) captured juveniles on mud flats and in all sections of rivers from the mouth to billabongs many kilometres from the sea.

Diet

In West Bengal, De (1971) reported that microcrustacea were the dominant component of the diet of *L. calcarifer* 10–15 mm long. As the fish grew he found their diet changed to predominantly insectivorous in fish 16–45 mm long and to mainly insects, fish and crustaceans in larger barramundi (50–200 mm long). In the Chilka Lake region of India, Patnaik and Jena (1976) also found the diet of juvenile *L. calcarifer* changed with size. Fish 24–50 mm long fed mainly on microcrustaceans, and larger barramundi (51–150 mm) ate mainly mysids, prawns and smaller fish. They found the diet of *L. calcarifer* over 150 mm was mostly fish and crustaceans.

In Papua New Guinea, Moore (1982) described the advantage gained by early juvenile *L. calcarifer* entering nursery swamps rich in zooplankton and insect larvae, presumably prey species. Dunstan (1959) sampled the gut contents of 96 barramundi of unspecified size from eastern Queensland. He concluded that barramundi are predacious throughout their life cycle, consuming approximately 60% teleosts and 40% crustaceans. In northeast Queensland, Russell and Garrett (1985) examined the gut contents of juvenile fish from both nursery swamp and tidal creek habitats. They found barramundi from swamp habitats had a varied diet, with fish and insects the main components. In tidal creeks they found juvenile *L. calcarifer* fed primarily on fish and also on crustaceans with insects entirely absent from their diet.

In the Van Diemen Gulf area of the Northern Territory, Davis (1985b) sampled the stomach contents of juvenile and larval fish down to 4 mm in length. He concluded that barramundi were opportunistic predators, with an ontogenetic progression in their diet from microcrustaceans to fish. Davis (1985b) found very early juveniles <40 mm long fed exclusively on microcrustaceans. In larger fish, microcrustaceans

became progressively less common in the stomach contents and absent in the diet of fish longer than 80 mm which fed on macrocrustaceans, other invertebrates and some fish. Fish and macrocrustaceans were equally important in the diet at about 300 mm and in larger barramundi fish was the dominant component (Davis 1985b). Davis collected similar data for juvenile *L. calcarifer* from the Gulf of Carpentaria.

Cannibalism appeared quite common in juvenile barramundi (Moore 1971; Davis 1985b). Moore (1980) reported its occurrence in nursery swamps in Papua New Guinea, while in Australia Davis (1985b) found barramundi had the capacity to consume other barramundi up to half their own size.

Nursery Habitats

Studies in Asia, Papua New Guinea and Australia have referred to juvenile barramundi utilising estuarine habitats, particularly wetland areas, as nursery habitats (e.g. Davis 1985a,b; De 1971; Ghosh 1973; Kowtal 1977; Moore 1980, 1982; Mukhopadhyay and Verghese 1978; Patnaik and Jena 1976; Russell and Garrett 1983, 1985).

ASIA

Kowtal (1977) collected juvenile barramundi from many estuaries on the east coast of India. Mukhopadhyay and Verghese (1978) noted that *L. calcarifer* juveniles ascended into estuaries and brackishwater lagoons in search of food and shelter. In the Bay of Bengal, Patnaik and Jena (1976) found juveniles entered the estuarine system of Lake Chilka from July to September.

A number of Indian authors have described the preferred habitat of juvenile barramundi inside estuaries. In West Bengal, De (1971) observed juvenile *L. calcarifer* as small as 10 mm in inundated tidal pools and swamps. He found juveniles 10–15 mm in length entered these habitats with tidal water, and apparently used the sheltered marginal areas as nurseries for only short periods before re-entering tidal waters. Ghosh (1973) found juvenile and larval *L. calcarifer* in estuarine creeks, canals and inundated low-lying areas in the Hooghly-Matlah estuarine system from May to July.

Barlow (1981) reported Thai studies that found larvae and early juveniles entered a mangrove swamp in the Songkhla lakes region. Juveniles remained in this nursery area for 4–8 months before they re-entered the lake.

PAPUA NEW GUINEA

Dunstan (1962) undertook one of the earliest investigations of the biology of barramundi in Papua New Guinea. This study concentrated mainly on the adult stocks, but he did observe that immature fish, while occasionally being caught in coastal waters during the seasonal spawning migration, were usually found in freshwater swamps and lagoons.

More extensive studies of juveniles of wildstock barramundi in Papua New Guinea were made by Moore (1980, 1982) and Moore and Reynolds (1982). Using tag recapture techniques, these authors produced evidence for a major migration to a common spawning ground in nearshore coastal waters of the southwestern Gulf of Papua. Larvae left coastal waters a few days after hatching and entered coastal swamp systems (Moore 1980, 1982). He described these nursery swamps as both rich in prey, in the form of zooplankton and aquatic insect larvae, and with virtually no large predators. In such ideal conditions, *L. calcarifer* quickly established themselves as the dominant predator (Moore 1982). Juveniles remained in the swamps until they had attained a length of about 200--300 mm, and then returned to coastal waters as the swamps began to dry out around June or July (Moore 1982). By the end of the their first year, juvenile barramundi had become widely distributed throughout coastal and estuarine regions and had dispersed into inland waters by their second and third year of life (Moore and Reynolds 1982).

AUSTRALIA

Studies on nursery habitats of juvenile barramundi have been undertaken in Queensland (Dunstan 1959; Russell and Garrett 1983, 1985; Davis 1985a) and in the Northern Territory (Davis, 1985a).

Queensland Dunstan (1959) established a relationship between the presence or absence of major river systems and the habitat type utilised by juvenile barramundi. In areas without major river systems, he observed barramundi of less than 25 mm swimming up shallow gutters into waterholes on flood plains, usually in close proximity to coastal waters. With the recession of flood waters, these fish became landlocked until the following wet season. However, in coastal areas with major river systems, Dunstan (1959) observed a different pattern of behaviour. Early juveniles moved upstream from the spawning grounds and many fish eventually were stranded in freshwater lagoons associated with the main river. Juvenile riverine fish grew quickly and progressively moved into freshwater reaches during the dry winter months.

More recently, both Russell and Garrett (1983) and Davis (1985a) described the use made by juvenile barramundi of temporary supralittoral habitats in the southern Gulf of Carpentaria. Here Russell and Garrett (1983) found that juveniles as small as 9.5 mm moved into temporary pools created by high seasonal tides from about the end of December. Davis (1985a) first captured barramundi in early January. Juvenile barramundi were extremely mobile, continuously entering and presumably leaving these habitats (Russell and Garrett 1983). The ability of *L. calcarifer* to exploit these shallow, prey-rich habitats was seen as

important for their early rapid growth and enhanced survival (Russell and Garrett 1983; Davis 1985a). Environmental conditions in these temporary pools were, at times, seemingly harsh. Russell and Garrett (1983) recorded fluctuations in temperatures and salinity of the pools which were, in some instances, extreme but the juvenile barramundi appeared to be tolerant of these conditions. They found that all resident barramundi must abandon these pools just before seasonal falls in tidal heights complete their isolation from the rest of the estuary or perish as they dry out.

In northeastern Queensland, Russell and Garrett (1985) found that the nursery habitats of juvenile barramundi were different to those encountered in the Gulf of Carpentaria by Russell and Garrett (1983) and Davis (1985a). These authors found that in coastal areas without large river systems, swamps formed the predominant nursery areas. In estuaries, juvenile barramundi first appeared in swamp habitats around February and later, about April, in tidal creeks. These coastal swamps had salinities varying from fresh water to 36‰. As in the Gulf of Carpentaria (Russell and Garrett 1983; Davis 1985a), these swamps were sheltered and presumably highly productive environments, conducive to the rapid growth of the juvenile fish prior to their movement back into the open estuary. From about April, Russell and Garrett (1985) found juvenile barramundi in fish samples taken from nearby tidal creeks. These authors concluded that lowering of water levels in the coastal swamps at the end of the wet season and a depletion of food supplies were major factors contributing to the exit of juvenile barramundi to more permanent habitats. Moore (1982) discussed similar escape strategies for barramundi resident in coastal swamps in Papua New Guinea.

Northern Territory Davis (1985a) reported on aspects of the biology and ecology, including nursery habitats, of juvenile barramundi in the Van Diemen Gulf area of the Northern Territory. In the 1978-79 spawning season, juveniles from 12 to 27 mm were first captured in January in a plankton net in the upper reaches of tidal creeks in the Mary River system. Later in February, Davis caught juveniles of 64-172 mm length in the extensive flood plain waters bordering the tidal section of the South Alligator River and in billabongs up to 25 km inland of tidal waters. In the following months, barramundi were caught in gillnets set in all sections of the surveyed rivers and on tidal mudflats.

In the 1979–80 barramundi breeding season Davis (1985a) closely monitored a tidal creek-swamp system near Darwin using a tidal trap to determine at what size and in what manner juveniles moved into inland waters. Juveniles as small as 8.3 mm were trapped on spring tides from October to February. The swamp and feeder streams were utilised as nursery areas during the summer monsoon period, and juvenile barramundi gained access to them during high spring tides. The vast aquatic habitats of floodplains and billabong systems formed during the summer monsoon provided prey-rich, relatively predator-free, environments which promoted rapid growth of the young barramundi (Davis 1985a). Barramundi have an extended spawning season and Davis (1985a) commented that juveniles from late spawnings might not find nursery habitats predator-free, as they would have been occupied by larger barramundi from earlier spawnings. He noted that barramundi were cannibalistc and capable of eating prey barramundi up to half their own length. Davis (1985a) also suggested that if the monsoon was delayed or interrupted, juveniles from early spawnings could perish as nursery swamps failed to form or dried out. In this situation, juveniles from later spawnings could take full advantage of nursery habitats.

Discussion

The value of coastal wetlands as nursery areas for fish has long been recognised (e.g. Austin and Austin 1971; MacNee 1974; Snedaker 1978; Weinstein 1979; Newell 1981). MacNee (1974) concluded that mangrove wetland areas were important refuges for many varieties of fish at a time when they were particularly vulnerable to predators. Newell (1981) suggested that mangrove wetlands provided shelter for fish life by offering concealment from large predators. In North Carolina, Weinstein (1979) identified shallow marsh habitats as primary nurseries for fishes and shellfish. He found the shallow tidal creeks and marsh shoals of the Cape Fear Estuary harbored dense populations of early juveniles of marine-spawned species.

Throughout its range, coastal wetland nursery areas appear to be an important link in the life cycle of barramundi (De 1971; Moore 1980, 1982; Russell and Garrett 1983, 1985; Davis 1985a). These shallow, productive environments provide for rapid growth and enhanced survival of juvenile barramundi at a time when they are most vulnerable to predators (Moore 1982; Russell and Garrett 1983, 1985; Davis 1985a).

Despite the acknowledged ecological significance of wetlands to juvenile barramundi, little work has been done to determine just how critical wetland areas are to the life cycle of the species. No information is available on whether other habitats may be used as nurseries in areas in which coastal wetlands would normally be preferred. Russell and Garrett (1985) suggested that human interference with nursery swamps, which has occurred and is still occurring in many parts of the eastern Queensland coast, could lead to a decline in local barramundi stocks and their attendant fisheries. However they made no attempt to test this hypothesis. Snedaker (1978) drew attention to

the close relationship in tropical latitudes between the size and variety of fish catches and the size of coastal swamps, and suggested that for many species the relationship may be obligatory. Saenger (1979), in a study of a coastal canal development in subtropical Australia, produced evidence showing that modified mangrove areas have reduced populations of juvenile fish.

If a direct relationship exists between juvenile nursery areas and barramundi stocks, then perhaps it is fortunate for the Australian barramundi fishing industry that much of northern Australia is still isolated, sparsely populated and industrially underdeveloped. Development has occurred on the east Queensland coast, which has major urban and industrial centres as well as an intensive agricultural base. There are instances where known barramundi nursery habitats along the east Queensland coast have been reclaimed for agricultural or industrial development (Russell and Garrett 1985). In the region in which this has occurred, the commercial barramundi fishery was small, being only a fraction of the catch in the more remote fisheries of the Gulf of Carpentaria (about a third in 1985) and the Northern Territory. The limited fishery statistics that are available indicate that the east coast barramundi fishery has been in decline in recent years. Figure 1 shows annual landings of wholeweight barramundi at a major fish processor for 30 years prior to 1981. While catches are variable, there has been a general decline over the entire period. It would be incorrect to suggest that destruction of nursery habitats is the sole or perhaps even the major cause of this decline, since other factors, such as over-exploitation must also reduce stock numbers.

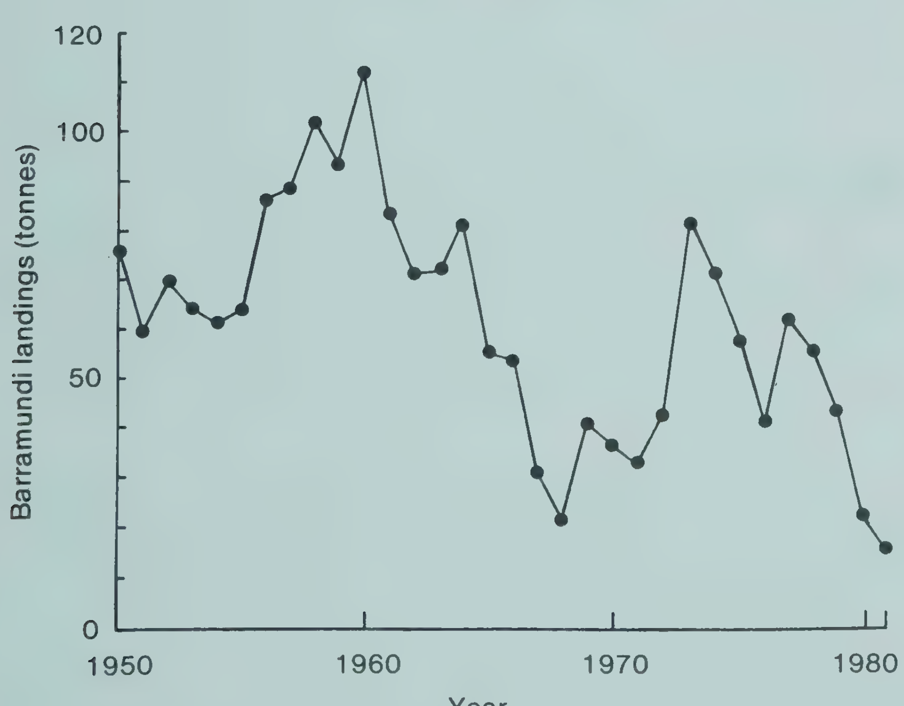

Fig. 1. Annual barramundi landings (wholeweight) at east Queensland coastal depots of the Queensland Fish Board from 1950 to 1981.

Coastal development is likely to continue in eastern Queensland. A shortage of suitable industrial and agricultural sites will ensure that further reclamation of wetlands takes place. It would be inadvisable to ignore the direct and very important contribution wetlands make to fisheries and indirectly to local economies. Amateur and professional fishing bodies in eastern Queensland, recognising the potential deleterious effect of habitat modification, are becoming increasingly vocal on such issues. While such groups are effective in political lobbying, further safeguards are needed. At the planning stages, when impact studies for such developments are undertaken, a positive effort should be made to identify important habitat areas and to assess the effect of their development on local fisheries stocks.

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Review of the Barramundi Fishery in Papua New Guinea

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THE barramundi *(Lates calcarifer)* fishery ranks fourth amongst the commercial fisheries after tuna, prawns, and lobster in terms of total fisheries production as well as foreign revenue earnings to Papua New Guinea. Its distribution over a large area, accessed by a large number of fishermen, makes it a difficult fishery to manage. Its vulnerability to overfishing is also emphasised by the rapid development of the fishery based on the largest stock of which the major recruitment is from a single spawning and nursery area.

Distribution and Abundance

The distribution of *L. calcarifer* in PNG has been described by Dunstan (1961, 1962), Reynolds (1972, 1978) and Moore (1980). In PNG the species occurs only on the south coast from Mullins Bay in the east to the border with Irian Jaya in the west. Its distribution continues westwards into Irian Jaya. It is absent from the north coast of New Guinea mainland and the New Guinea islands. The distribution and abundance appears to be related to the occurrence of large deltaic or swamp areas combined with large tidal variations. Although there are large rivers on the north coast of New Guinea (e.g. Ramu and Sepik) where large flood plains also occur, the tidal variation is relatively small, e.g. 0.6 m compared with 4.0 m (Moore 1980), and there are no deltas. The combination of tidal variation with large deltaic-swamp areas increases in magnitude from east to west on the south coast. The rivers draining Central and Eastern Papua are rather short, fast flowing, have relatively less extensive swamp systems and a tidal variation of 2.7 m. These support a much reduced barramundi stock. In the Laloki system near Port Moresby, barramundi are known to extend 80 km upstream (Berra et al. 1975). The Fly River system, to the west, is the largest delta-swamp in PNG with tidal variations of 4.0 m. Here barramundi are quite common 800 km upstream (Moore 1980).

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Biology

Studies on the biology of *L. calcarifer* in PNG waters coincided with the rapid development of the commercial fisheries particularly in the Daru Coastal and the Fly River system in the 1970s. Reports from Queensland, Thailand and the Philippines generally stated that there was a decline in their stocks due to commercial fishing. Hence, in PNG, fishermen had expressed their opinion as early as 1969 that if the fishery in Western Gulf of Papua developed without restriction, there would be a stock depletion (Moore 1976). Two scientists were therefore recruited; one to study general biology, and one to coordinate the overall program and to study the population dynamics and the development of management measures (Moore 1980).

An extensive study of the biology and population dynamics of barramundi took place between 1970 and 1974. Results of these studies have been widely published both in PNG and overseas (Anon 1973; Moore 1976, 1979, 1980, 1982; Moore and MacFarlane 1976; Moore and Reynolds 1982; Reynolds 1972, 1978; Reynolds and Moore 1982).

Reproduction

Lates calcarifer in PNG is a protandrous hermaphrodite (Moore 1982). Males mature at 3 to 5 years, whilst secondary females become mature at 8 or 9 years. There are some primary females which mature at 73 cm or 6 years. Fecundity in barramundi is very high. Moore (1982) sampled fish of weights ranging from 7.7 to 20.8 kg, and gave fecundity estimates of 2.3×10^6 to 32.2×10^6 eggs per fish.

Life Cycle

The major spawning area is between Sigabaduru and Jarai with a minor one at Kiwai Island. The eggs hatch in coastal waters near coastal swamps during the months of November to February, and the larvae (<5 mm) migrate into the coastal swamps through the drainage channels during the spring tides when a shallow saltwater 'bridge' is formed connecting the

coastal waters and the swamps. Around March–July, at the approach of the dry season, the juveniles migrate back to coastal waters. Most of these are 20–30 cm long and 0+ age-class when they leave the swamp systems. They congregate on the coast until they are 6–12 months old. Migration into inland waters begins when they have reached the age of 1+ years old. This migration is not entirely uniform as some migrate 1 or 2 years later than this. Not all fish migrate as there seems to be a resident population of all age groups that remain in coastal waters. The spawning migration from inland waters is from September to January. Most fish that take part in this spawning migration are 3–4 years old. Moore (1982) indicated that a high spawning migration corresponds to a substantial lowering of inland water level. Post-spawning migrations back to freshwater also occur and some fish may repeat the spawning cycle, but not every year.

There are two interesting facts about the spawning migration. First, fish which move to inland habitats and then undertake the spawning migration, do not become resident on the coast, but return to inland waters after spawning. Second, despite the apparent mixing during the spawning migration, fish from the Fly River system and the Northern Gulf return to their respective areas after spawning (Moore and Reynolds 1982).

Growth Rate

The life history of barramundi is complex and the growth rate varies considerably with its life stages. Reynolds (1978) showed that fish grow faster in freshwater than in saltwater habitats. Similarly, because of sex inversion most fish smaller than 75 cm are males whilst most fish larger than 100 cm are female, hence the upper portion of the growth curve could be diphasic (Moore 1982). By using tag recoveries and modal-progressions from length-frequency data, Reynolds and Moore (1982) calculated a table for length at age and suggested that this represents the whole population.

History of Commercial Exploitation

The investigations, including netting surveys of barramundi, began in 1957 in the vicinity of Port Moresby, by the Division of Fisheries of the then Department of Agriculture Stock and Fisheries (DASF). By 1961 surveys had extended to the rivers discharging into the Gulf of Papua, while operating off a shore base at Daru, Western Province.

Following these investigations commercial fishing areas were identified at Galley Reach, Yule Island, Lake Murray, Daru, Morehead and Bensbach. Processing and distribution centres were later set up near these fishing grounds at Port Moresby, Yule Island and Daru. Records are only available for the Daru-based fishery which produced 206.66 t and 134.102 t of whole fish in 1969 and 1970 respectively (Reynolds 1972).

By 1979, three operations were established in Western Province (Moore and MacFarlane 1972): (1) Daru coastal fishery; (2) refrigerated fishing vessels; and (3) village-based freezers.

The Daru coastal barramundi fishery was based on the seasonal breeding migration (September–January). All the fishing operations were undertaken by local fishermen and the catch was either taken to processing plants at Daru or to freezer vessels anchored close to fishing grounds. Only one plant is operating today at Daru.

Freezer vessels (14–16m) with freezer capacities of 5–12 t fished out of Daru near the mouth of the Fly during the spawning migration. During the non-migration period their operations moved up into the Middle Fly including Lake Murray and occasionally to other associated waterways as well. Although catches per unit effort were usually lower in the inland than in the coastal fishing areas, excellent catches were sometimes taken when water levels dropped. Fishing throughout the year, however, was more beneficial for a constant supply of product.

Freezers of approximately 5-t capacity were established at Boset in the Middle Fly and on Samari village on Kiwai Island in the mouth of the Fly River. Fishing to supply these freezers was mainly from outboard-powered dinghies and canoes using 160–200 mm mesh gillnets. Supervision of these freezers was provided by resident missions and ownership by the villagers through their village cooperatives. The fish were filleted and packed in the villages and sold to either the freezer vessels or to the plant at Daru.

Other freezers with capacities of 0.5 t were also set up in remote areas. However, these were later discouraged due to difficulties in clearing the freezers on time and maintaining the quality of the product.

The Present Fisheries

Barramundi comprises the major resource of villages where fish and other freshwater and marine resources represent the major cash income. Most barramundi fishermen live in areas of very little agricultural potential and their main fishing crafts are sail powered dugout canoes. Outboard motors on dugouts or aluminium dinghies are used by the few barramundi fishermen who can afford them. Today, there are only two fishing centres in operation. The Daru fishing centre in the Western Province is owned by the Western District Seafoods Pty. Ltd. and the Baimuru fishing centre in the Gulf Province is owned by the Baimuru Fishing Company Ltd.

The Daru-Based Fishery

The present commercial fishery of the Western Gulf of Papua exploits the area of the Fly River–Lake Murray systems (Inland Fishery) and along the coast from the mouth of the Fly River to the mouth of the Binaturi River west of Daru.

Nets being used in this fishery are monofilament and multifilament gillnets of 178 mm mesh size and usually 100 m long by 4.0 m or 25 meshes deep. Along the coast, nets are set at right angles to the shore and are cleared every 6–8 hours. In the inland areas, nets are set at about right angles to the bank of the rivers and within the lakes. Village fishermen in the vicinity of Daru land their product directly to the Western District Seafoods (WDSF) factory. Those who are able to, fish up to 20 km away using outboard powered canoes or dinghies. Observations at the factory indicated that 20% of the catch brought in by the village fishermen is rejected annually. A large number of fishermen therefore rely on the presence of freezer vessels.

The freezer vessels, mostly of Australian origin, are especially designed for operating in shallow/tidal waters and are usually equipped with gillnets, processing facilities and carry store goods for trading. Their freezing capacities of 2–6 t of barramundi fillets enable them to operate over extended periods of 2–4 weeks. The last vessels, however, stopped operating in 1984.

The area from Sui to the mouth of the Binaturi River is reserved for local fishermen. Licensed foreign freezer vessels that are allowed into this area operate only as 'mother boats.' Fish caught around Daru and sold directly to WDSF obtained 80 t/kg gutted. Fish caught further away and sold to freezer vessels obtained 30–40 t/kg gutted in the inland grounds and 60 t/kg gutted at coastal grounds (100 t = NGK1 = $1.6 Aust). The freezer vessels land the fish at K3.50/kg of processed fish to the WDSF at Daru. These frozen fillets are then packed in labelled packets and shipped by sea or air to either Port Moresby or Australia.

Since its commencement in 1970, the Daru-based fishery has experienced a period of fluctuation until 1985 when the production reached its lowest. The annual landings for this fishery from 1971–72 to 1984–85 are given in Table 1. The inconsistent fishing operation of the freezer vessel contributed considerably to this fluctuation.

Daru CPUE

Collection of catch and effort data for the Daru fishery (Coastal and Inland) commenced in 1980. A simple catch return form was adopted for use by the freezer vessels while at the WDSF factory a catch form was used to collect total catch at the WDSF factory.

The effort of the freezer boats fluctuated between 917 hundred metre net days (hmd) in 1980 and 4 164 hmd in 1982. The CPUE, however, has been reasonably steady at an average of 28.6 kg/hmd (Table 2). The steady state may not necessarily relate to a constant stock because there may have been an increase in fishing efficiency. The number of freezer vessels also fluctuated between 1972 and 1985, because of various reasons including political and economic.

Table 1. Annual landings of the Daru-based barramundi fisheries (t, whole weight).

Season	Total
1971–72	394
1972–73	241
1973–74	284
1974–75	352
1975–76	179
1976–77	210
1977–78	170
1978–79	207
1979–80	221
1980–81	308
1981–82	328
1982–83	187
1983–84	139
1984–85	87
1986 (Aug.)	7

Table 2. Barramundi catch and effort data from several freezer vessels in the Daru-based commercial fishery.

	Total Fishery			
Year	Effort 100m net days	Catch (kg whole)	Days	CPUE (kg/100 m net days)
1980	917	46 737	123	51.0
1981	1 527	37 355	114	24.5
1982	4 164	98 760	233	23.7
1983	1 871	46 755	137	25.0
1984	3 986	87 419	206	21.9
1985	1 278	32 778	75	25.6
Average	2 291	58 301	148	28 6
SD	1 418	27 720	60	11.0

The Baimuru-Based Fishery

The Northern Gulf extends from the Turama River to the Purari River in the east. Much of this area consists of mangrove and swamplands. The main rivers are Turama, Kikori, Era and the Purari. A tidal influence is experienced up to 80 km inland, while much of the coastal delta is inundated during the high spring tides.

Freezers of 0.5 t capacity were located at Ihu, Baimuru and Kikori. At Kikori the government freezer was producing 12 t of barramundi and 15 t of mixed fish fillets by 1977 (Anon 1976). This operation ceased because the remoteness of the area made it difficult to clear the products quickly and to keep high quality control.

In 1979, an old hotel in Baimuru was converted into a processing plant with a 5-t holding freezer. The government signed a loan agreement with the International Funding for Agriculture Development (IFAD) in 1983 for funding of two coastal fisheries centres at Samarai and Baimuru. The main objective was to promote the artisanal fisheries in these two areas, where there is very little arable land for agricultural development. The Baimuru component of this loan was around K4.0 million for the establishment of more freezers and operational costs, the construction of a wharf and more housing for staff, and purchase of collection vessels. During 1982–83 the Baimuru Fishing Company Ltd. (BFC) was established at Baimuru, and in 1984 a substation was opened at Kikori to produce iced fish for processing at Baimuru.

The Baimuru-based fishery is a village fishery deploying no freezer vessel. The catch is either brought into Baimuru or Kikori or to any of the collection stations strategically situated in the delta. The collection stations comprise 0.3–0.5-t ice boxes. The iced fish is brought back to Baimuru by large dugout canoes and dories owned by the BFC. The annual production has been increasing at a steady rate since 1982. The CPUE increased from 5.1 kg/hmd in 1982 to 27.8 kg/hmd in 1986. This increase reflects both the increase in the number of nets being introduced into the fishery as well as an increase in fishing efficiency.

For any management strategy to be effective, however, the whole area (Coastal, Inland and Northern Gulf) will have to be looked at both individually and collectively. Biologically, what happens at any one of the fisheries will eventually affect the whole stock.

Subsistence Fishery

Haines (1979) estimated the subsistence fishery in the Purari and Kikori delta to be 600 t of fish per annum from village catches. He noted that a large part of the catch included small fishes such as gobbies, perchlets, gudgeons and small catfish. Most barramundi in this area were too large, however, to be caught in the subsistence fishery because the gear they were using was not capable of catching large fish.

In the coastal fishery of the Western Province juvenile barramundi are particularly important in the subsistence fishery. Moore (1976) pointed out that two methods used in catching juvenile barramundi were derris poisoning of the nursery swamps and the use of small-mesh gillnets in coastal waters.

The subsistence fishery in the coastal waters is increasing in magnitude and may warrant some form of conservation measures particularly concerning the use of small mesh gillnets (Fisheries Officer in Daru, pers. comm.). Apart from the subsistence surveys in the Purari area, there has not been any other detailed study on the subsistence fishery in this area to quantify the catch, the species involved and traditional knowledge.

Other Studies

Although 'management' and 'conservation' of fisheries resources are included in the objectives of the Division of Fisheries in PNG, 'to encourage and facilitate the exploitation of PNG's fisheries resource' is the first objective. Many of the PNG fisheries resources are still in the developing stages, except for prawns, lobster and barramundi. Developments in these three fisheries are being monitored with regard to management to conserve the stocks.

In line with the redevelopment of the Daru-based barramundi fishery and the development of the Baimuru-based fishery, two studies are being undertaken. One is an economic analysis of the barramundi exploitation by a Canadian consultant. The other is by Fisheries Research and concerns the estimation of yields. Field work for both of these studies has been completed and the results are being analysed. Both studies should be completed soon.

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Biological Characteristics of Wildstock Sea Bass *(Lates calcarifer)* in Thailand

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Lates calcarifer, commonly called sea bass or barramundi, and locally pla kapong kao, is an economically important food fish in Thailand. It grows to comparatively large size with delicate, flavoured flesh and commands a high price in the market. Though the Thais are successful in breeding and culturing sea bass, there is little known of the biology of the species (South China Sea Fisheries Development Coordinating Programme 1982; Kungvankij 1984; Maneewongsa and Watanabe 1984).

Distribution

Sea bass is a euryhaline and catadromous species. Spawners are found in the river mouths, lakes (e.g. Bang Pakong River on the east coast, Songkhla Lake located in the south and along the coastal area of the province facing the Indian Ocean) where the salinity and depth range between 30 and 32‰ and 10–15 m respectively.

They spawn during the incoming tide. This enables the eggs and the hatching to drift into estuarine brackishwater such as in mangrove swamps where they develop and undergo their larval stages. Sirimontaporn et al. (1984) surveyed the spawning ground of sea bass in Songkhla Lake. They found the largest number of eggs and larvae near the lake outlet at night. Among 435 eggs and larvae collected during the survey, 343 were collected at the same site (Table 1). A total of 412, 94.7%, were collected at stations 1–3 located in the mouth of Songkhla Lake. Some of the eggs moved into the lake as far as 5 km by the current and flowed out again to the sea on the ebb current. The larvae (15–20 days old or 0.4–0.7 cm) are found along the coastline of brackishwater estuaries and the fry above 1 cm in size can be found in both freshwater and brackishwater areas, e.g. in the rice fields, lake mangrove swamp, etc. (Bhatia and Kungvankij 1971).

Life History

Sea bass are carnivorous and fast-growing, feeding mainly on live food. They spend most of their growing period in fresh water such as rivers and lakes which are connected to the sea. Mature fish (< 3 years weighing 2–3 kg) migrate toward the mouth of the river or lake from the inland waters into the sea, where the salinity range is 30–32‰, for gonadal maturation and subsequent spawning. The fish spawn according to the lunar cycle. The fertilised eggs were collected at the mouth of Songkhla Lake from the first night till the fourth and fifth after the full moon from 2100–2300 hours, coinciding with high tide (Sirimontaporn et al. 1984). This showed that the fish spawn according to the lunar cycle between 1800 and 2300 hours, coinciding with the incoming tide. This allows the eggs to drift into estuaries. Here, larval development takes place after which they migrate further upstream for growth. It is not known whether the spent fish migrates upstream or spends the rest of its life in the marine environment.

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Table 1. Number of sea bass eggs and larvae collected around the mouth of Songkhla Lake. Source: After Sirimontaporn et al. (1984).

	Station															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
July 26		0	0	0	0	0	0	0	0							
July 27 morning		0	0	2	1	0	0	0	0							
July 27 night		8	277													
July 28 morning		27	14	25	0	0	0	0	0	0	3	2	0	0	7	1
July 29 morning			4	7	1	0	0	5	0	0	0	3	0	0	0	0
July 29 night	0	0	48			0	0									

Fecundity and Spawning

Identification of the sexes is difficult, except during the spawning period. The males are usually smaller with slender shape and narrower body. At the ripe stage, the milt can be extruded from the genital opening with slight pressure on the belly. On the other hand, the female spawners can be recognised for their big soft round belly and red-pink papilla extending out at their urogenital aperture. If fully ripe, eggs can be extruded by applying gentle pressure on the abdomen from the anterior towards the posterior with the thumb and forefinger. The eggs should flow out. The fecundity of sea bass is related to the size and weight of the fish. Females weighing from 5.5 to 11 kg gave 2.1–7.1 million eggs (Wongsomnuk and Maneewongsa 1974) (Table 2). Sea bass in Thailand spawn all year, the peak season at Songkhla Lake occurring during April–September. A large number of fry can be collected during May–August along the coast and in the rice fields (Bhatia and Kungvankij 1971).

Table 2. Relationship between size of fish and number of eggs. Source: After Wongsomnuk and Maneewongsa (1974).

T.L. (*cm*)	Weight (*kg*)	No. of fish	Fecundity range	Average (*million eggs*)
70–75	5.5	3	2.7–3.3	3.1
76–80	8.1	5	3.1–3.8	3.2
81–85	9.1	4	5.8–8.1	7.2
86–90	10.5	3	7.9–8.3	8.1
91–95	11.0	3	4.8–7.1	5.9

Embryonic Development

The beginning of embryonic development takes place 35 min after fertilisation. The approximate time and duration of the various embryonic states of sea bass are given in Maneewong's paper (these Proceedings). The hatching takes place about 17–18 hours after fertilisation at 27–29 C, 30–32‰.

Sea Bass Larvae

Newly hatched larvae are 10.6 ± 0.04 mm TL (Kosutarak and Watanabe 1984) with a big yolk sac. The yolk sac has one big oil globule (0.2–0.28 mm) at its anterior. This enables the larvae to be set in the water with head raised at a 45–90° angle. The body is slender and pale in colour with a distribution of pigments. The eyes, digestive tract, anus and caudal fins are distinctly seen but the mouth remains closed. The mouth opens when the larvae are 3 days old and the yolk has been almost completely absorbed. The larvae start to feed on tiny organisms such as rotifers. Up to 7 days old, the larvae are pale in colour and from the age of 7 days to metamorphosis at 18–20 days, they appear dark with distinct vertical stripes on certain parts of the body. After the 18th–20th day, the larvae again assume a pale brownish colour. This time, the vertical stripes can be more clearly distinguished. There are three stripes, one at the caudal peduncle, another at the level between the first or spinous dorsal fin and the second or soft dorsal fin, and a third over the head, all of which are particularly distinct. In 1 month, the larvae metamorphose into the fry stage which has an appearance very close to the parent fish. The fry measure 1.5–2.0 cm. These further grow and develop into juveniles after the third to the fifth month when they attain 8–15 cm.

Feeding Habits

The adult sea bass is regarded as a carnivore, but juveniles are omnivores. Analysis of stomach content of wild specimens (1–10 cm) found about 20% plankton (primarily diatoms and algae) and the rest are small shrimp, fish, etc. The stomach content of the larger fish consists of 100% animal prey: 70% crustacean (shrimp and small crab) and 30% small fishes (Bhatia and Kungvankij 1971).

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Review of the Sea Bass *(Lates calcarifer)* Fishery in Indonesia

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INDONESIAN fisheries are dominated by small-scale operations, characterised by low technological inputs with low productivity. It is estimated that small-scale fisheries contribute about 90% of the total fish production.

The marine fishery production of Indonesia increased by almost 7% per year during 1976–85 (Table 1), of which about 0.01% is sea bass *(Lates calcarifer)* catches. (For details see the 'Fisheries Statistics of Indonesia,' for the years 1976 to 1986.) The catch of sea bass during 1976–84 increased about 3.6% annually, although with some fluctuations during the period.

Table 1. Marine fishery production (tonnes) and sea bass *(Lates calcarifer)* in Indonesia. (Source: Fisheries Statistics of Indonesia.)

Year	Sea bass	Total production
1976	2020	918936
1977	1790	976700
1978	9314	1029335
1979	8456	1120669
1980	10938	1218167
1981	9845	1206983
1982	9697	1326447
1983	14158	1467824
1984	12609	1529553

The other sea bass production comes from brackishwater culture as a by-product. The by-product during 1980–84 decreased 1.5% annually (Table 2).

The sea bass is well known in Indonesia, and is one of the high-value table fish with a good demand. Although available in small quantities sea bass is one of the commodities being exported to neighbouring countries (i.e. Singapore and Australia).

The average individual weight of sea bass caught in marine waters is usually not more than 7 kg, while those harvested from brackishwater ponds weigh 400–600 g. Lack of a supply of uniform size sea bass has been a major constraint for many restaurants. With

Table 2. Brackishwater culture (tonnes) of sea bass by province. (Source: Fisheries Statistics of Indonesia.)

Province	1980	1981	1982	1983	1984
D.I. Aceh	112	208	206	178	51
Sumatera Utara	7	14	11	1	1
Riau	—	1	2	3	2
Lampung	—	3	5	6	6
D.K.I. Jakarta	3	3	8	11	1
Jawa Barat	113	123	269	222	220
Jawa Tengah	58	94	59	164	43
Jawa Timur	63	88	111	113	92
Nusa Tenggara Barat	3	—	—	—	—
Kalimantan Timur	8	15	25	29	32
Sulawesi Selatan	453	334	259	315	285
Sulawesi Tenggara	—	—	11	63	—

the growth of restaurants serving fish food, the culture of sea bass becomes a promising venture. To support sea bass culture, availability of seed is one of the key factors. The establishment of hatcheries is needed since the supply of fry from natural waters is not reliable.

Distribution

In Indonesia sea bass are distributed throughout the country in the coastal area, estuaries, lagoons, brackishwater ponds (as unwanted species which enter the pond with high tide), river mouth waters and upstream waters.

It has been reported in all 27 provinces, which are summarised in 11 statistical coastal areas. The West Coast of Sumatera, East Coast of Sumatera, Bali and Nusatenggara, South and West Coast of Kalimantan, East Coast of Kalimantan, South Coast of Sulawesi, and Maluku and Irian Jaya waters are those with high production.

Fishing Gear

Sea bass are caught by fishermen using a variety of fishing gear, including gillnets, seine nets (pukat kantong), hook and lines, trap nets and others. Before trawling was banned, the species was also caught by trawlers.

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Using data available from some major fishing areas, the contribution of the main fishing gear to total catch of sea bass is as follows: East Coast of Kalimantan (East Kalimantan Province and South Kalimantan Province): Gillnets: The gillnet contributed 69.5% of total sea bass catch in 1984, followed by trap nets 16.3%, hook and lines 13.1%, and others 0.9%; and East Coast of Sumatera (South Sumatera Province, Jambi Province and Lampung Province): The gillnets contributed 64.7% of total catch of sea bass in 1983, followed by hook and lines 27.4%, seine nets 7.9% and others 0.9%.

Production

The fishing season for sea bass production varies from area to area. Based on estimations of Fishery Potential in Indonesia (1974) fishing takes place throughout the year in North Sumatera, Jambi and West Nusa Tenggara.

In Bengkulu Province fishing extends from October to December, in Lampung Province from February to June, in Jakarta from December to January, in West Java from October to March, in South Kalimantan from April to December. The fishing seasons in other provinces were not reported.

Brackishwater Culture

As the by-product of brackishwater culture, the sea bass harvest in 1980–83 increased steadily from 850 to 1105 t or 9.2% annually and decreased considerably to 733 t in 1984 or 33.6%. The major production areas for brackishwater ponds in 1983–84 are in West Java, East Java, South Sulawesi, Aceh, Central Java and East Kalimantan (Table 2).

The Future of Sea Bass *(Lates calcarifer)* in Indonesia

Although the overall exploitation of marine fish resources is still at a low level (around 25%) some fishing grounds have been heavily exploited and are known as 'critical waters.' Before the trawl ban in 1980, the critical fishing grounds were Malacca Strait, Cilacap, Bali Strait, and off the north coast of Java.

Future fish landings from marine waters, especially coastal waters, will decrease considerably. To solve the problem encountered by the heavily exploited fishing areas the Indonesian government is encouraging fishing in offshore waters or moving to the underexploited fishing grounds (coastal and offshore). The government is encouraging the development of marine fish culture ventures.

In recent years, the culture of sea bass, especially those in floating nets, has developed rapidly, particularly in Hong Kong, Malaysia, Singapore and Thailand. Marine finfish culture is still new in Indonesia. Research and development in this field started in 1979.

A research laboratory in Banten Bay and a development centre in Lampung Bay were established in 1980 and 1984 respectively. The research program includes basic fishery biology, finfish culture and shellfish culture. The Development Centre in Lampung is responsible for the application of research results and to disseminate them to fish farmers through extension activities. In this regard, test farms or pilot projects have been established in Riau, Jakarta, Bali and Lampung. So far progress in Riau has been encouraging. Culture trials of sea bass in the Development Centre, Lampung, are now underway and will be reported on elsewhere.

Based on known coastal environmental conditions, certain areas have been identified for marine culture development. Riau, Lampung, West Java, East Java and Bali are among those potential areas for finfish culture development, although test farms should be established for further activities.

Status of Sea Bass *(Lates calcarifer)* Fishery in Indonesia

Wardana Ismail* and Edward Danakusumah**

In 1983, fisheries production in Indonesia was 2 214 000 t consisting of 76% marine fisheries, 12% inland open water fisheries and 12% aquaculture (Anon. 1985b). The production of sea bass *(Lates calcarifer)* was 15 260 t contributing 0.68% of the fisheries production or 0.61% of the total value. More than 90% of sea bass was produced from the sea (catching) and the rest from brackishwater ponds as a by-product of milkfish culture. Total production of sea bass caught from the sea consisted of 24.2% from Sumatra, 6.2% from Java, 28.8% from Kalimantan, 15.5% from Sulawesi, 8.8% from Bali and Nusa Tenggara, 16.6% from Mollucas and Irian Jaya (Anon. 1985b). Annual sea bass production during 1977–83 is shown in Table 1.

Table 1. Annual production of sea bass in Indonesia from 1977 to 1983 (Anon. 1985b).

Year	Marine (*t*)	Brackish-water pond (*t*)
1977	8817	659
1978	9314	371
1979	8456	745
1980	10 938	850
1981	9845	883
1982	9697	966
1983	14 158	1105

Sea bass is considered one of the important marine species. Among the marine finfish, sea bass ranks third. However, among the finfish produced in brackishwater ponds, price of sea bass is first (Danakusumah et al. 1986). Price of sea bass produced from brackishwater ponds is higher than that from the sea. The price is between 2000 (at pond) and 3000 Rp (at market) per kg (1$US = 1100 Rp).

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Possibilities of Sea Bass Culture

Indonesia has a long history of brackishwater culture with milkfish (*Chanos chanos*) as the main culture species (Schuster 1950). Sea bass, mullet (*Mugil* spp.), tilapia (*Tilapia mossambica*) and shrimps (*Penaeus* spp., *Metapenaeus* spp.) and brackishwater crab (*Scylla serata*) are by-products of the brackishwater culture (Danakusumah et al. 1986) so-called 'extraneous fish' (Schuster 1950; Bardach et al. 1972). According to the fisheries statistics in Indonesia (1983), the total brackishwater production was 134 072 t consisting of 60.8% milkfish, 20.5% shrimps, 9.3% tilapia, 3.1% mullet, 0.8% sea bass and 5.5% others. In traditional brackishwater culture methods over 4% of sea bass is possibly harvested as a by-product of milkfish culture (Danakusumah et al. 1986).

In present conditions, Indonesia has about 200 000 ha of brackishwater ponds (so called 'tambak'), distributed along the east coast of Aceh, north coast of Java and the South Sulawesi coast. Brackishwater culture is one of the possibilities for developing the sea bass fishery.

Sea bass, which is one of the promising species for finfish culture in Indonesia (Chan 1981), has a relatively high growth rate and is easily cultured. However, culture of piscivorous fish is dependent on high-protein feed such as formulated feed, or 'trash' fish. In Indonesia, the price of trash fish is high compared with the price of sea bass. Intensive sea bass culture using feeds is therefore not profitable. In the future, however, given higher market prices, brackishwater culture for sea bass may be profitable.

Pen culture and floating net cage culture may be other possibilities for sea bass, but are not profitable for the same reason.

Problems to be solved for sea bass culture in Indonesia are: (1) seed production from both natural water and possibly from hatcheries; (2) find cheaper feed; (3) to increase the market price and demand for the product; and (4) to develop more efficient culture techniques. Finding cheaper feed will be almost impossible because the raw material such as fish meal

is imported, and therefore expensive. On the other hand, the price of trash fish is not low either. Exporting the product may help increase the market price of the product. Developing more efficient culture techniques is probably the only way to solve the problem. Hence, research activities on sea bass culture are being accelerated.

Research

Several experiments on sea bass culture have been conducted in Indonesia. The results are summarised below.

Collecting Wild Sea Bass

In order to provide sea bass for experiments, fish were collected from the Sekampung Estuary, East Coast of Lampung Province (Sugama and Eda 1986). The fish were collected using a set net, gillnet, and a combination of shelter and gillnet. Sea bass fry 20–200 g were mainly caught at coastal waters using 'sero' at low tide. Fish of similar size can also be collected at brackishwater ponds or at the canals. Young sea bass 200–1000 g were caught using a gillnet on the river during evening. 'Spawners' of 3–14 kg were caught using a combination of shelter and gillnet at coastal waters (Anon. 1986). The salinity during the collection was between 20 and 30‰.

Transportation

Sea bass collected at Sekampung Estuary were transported to the Bojonegara Research Station for Coastal Aquaculture by a 10-t capacity research vessel. Fish were kept in an inboard tank (2 × 1 × 0.7 m) equipped with aerator. During the 7 hours transportation period the survival rates ranged between 97 and 100% (Anon. 1986). Fish usually suffered from stress and vomited (Danakusumah et al. 1986). The fish recovered after 3–4 days.

An experiment was done on transportation of sea bass juveniles (0.65 cm in average body length) from the National Institute of Coastal Aquaculture, Songkhla, Thailand, to the Bojonegara-Serang, West Java, Indonesia. The juveniles were adapted to fresh water before being transported. They were kept in a plastic bag filled with fresh water and oxygen at a ratio of 2:3. The survival rate during 38 hours transportation period was 98% (Anon. 1986).

Grow-Out Experiments

Result of grow-out experiments are summarised in Table 2.

Candidate spawners were collected from Sekampung Estuary. Nine individuals 7–12 kg were kept in a 125 m^3 tank (8 m diam, 2.5 m deep). Seawater (33–35‰) was constantly circulated and the water aerated with an electric paddle wheel. The fish were fed daily with prawn at a daily feeding rate of 2–3% of body weight. They were injected repeatedly with pituitary gland of silver carp and gonadotropin. During the experiment, only one female matured. On another occasion, some males matured. However, fertilised eggs could not be obtained (Anon. 1986).

Research Program

In line with the present status of sea bass fisheries, and in an effort to further develop sea bass culture, our research will emphasise the following: (a) breeding (raising spawners, natural or induced spawning and larval rearing); (b) cultivation (growing of juveniles to marketable size); (c) feed technology and nutrition; and (d) diseases and parasites.

Research on fishing techniques, distribution and potential stock of sea bass in Indonesian waters will also be considered as well as the socioeconomic aspects, such as marketing and culture management.

In the Agency of Agricultural Research and Development (AARD) organisation, the Central Research Institute for Fisheries (CRIFI) has responsibility for coordinating research programs on fisheries in Indonesia. The program is classified as: (a) marine fisheries; (b) freshwater (pond) culture; (c) open water fisheries (rivers, lakes, man-made lakes and swamps); (d) brackishwater (pond) culture; (e) mariculture; and (f) fish technology.

The CRIFI is coordinating three research institutes. These are: (a) Research Institute for Marine Fisheries (RIMF), Jakarta; (b) Research Institute for Freshwater Fisheries (RIFF), Bogor; and (c) Research Institute for Coastal Aquaculture (RICA), Maros, South Sulawesi.

Table 2. A review of culture experiments of sea bass in Indonesia.

Net cage dimension (m)	Average body weight (g)		No. of fish (ind)		Period (day)	Food conversion Ratio	Feed	Source
	Initial	Final	Initial	Final				
5x4x3	10.0	73.0	2000	1492	150	20.0	trash fish	Anon 1985a
3x3x3	16.2	445.3	476	375	195	—	fish	Anon 1986
2x2x2	199.4	1871.1	35	18	370	7.1	sardine	Sugama and Eda 1986
3x1.5x1.5	244.9	900.0	43	43	152	8.1	trash fish	Chan et al. 1985
3x1.5x1.5	260.2	877.6	41	41	152	7.6	trash fish	"
3x1.5x1.5	436.1	1094.8	23	23		8.4	trash fish	"
2x2x2	1149.4	3327.9	25	22	370	8.5	sardine	Sugama and Eda 1986

Each institute has research stations with several mandates. Research dealing with sea bass culture is one of the RICA's mandates. At present, it is being conducted by RICA Bojonegara Station, West Java, whereas RIMF has a mandate to do research on fishing techniques, distribution and resource potential of sea bass.

In order to develop sea bass fisheries in the Indo-Pacific region, particularly in Indonesia, collaborative research among countries on sea bass should be considered. International organisations which have an interest in the development of fisheries in this region, such as FAO, SEAFDEC, ACIAR, JICA, IDRC, etc., should participate in the research program on sea bass through collaborative projects or technical assistance.

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Status of Sea Bass *(Lates calcarifer)* Culture in the Philippines

Romeo D. Fortes*

THE successful spawning of sea bass *(Lates calcarifer)* in Thailand in 1973 (Tattanon and Maneewongsa 1982) and in the Philippines in 1983 has attracted the attention of many fish farmers in Asia and the Indo-Pacific Region. Culture techniques for sea bass still require improvement, particularly pond culture techniques (Fortes 1985) which need to be refined and developed. In one study, it was noted that pond-grown sea bass seemed to enjoy a premium price over the wild-caught fish (Uwate et al. 1985). A culture fishery would therefore seem important. In the same study, it was indicated that, for the Philippines, pond polyculture of sea bass with milkfish *(Chanos chanos)* and tilapia *(Oreochromis mossambicus)* appeared competitive in terms of cost and returns estimates for the different sea bass culture systems in the region. The production and market estimates therefore indicate that, in the short run, the sea bass pond polyculture system has a bright future. Very little has been done on the culture of sea bass in cages in the Philippines, due to the very limited availability of trash fish which is the major food source of sea bass.

In addition, the absence of acceptable formulated feed and undeveloped market limits the number of fish farmers into sea bass culture. Although sea bass will not replace the approximately 200 000 ha of milkfish ponds, it can provide a very good opportunity for the fish farmers to diversify their production which would enable them to obtain additional returns.

This paper attempts to integrate the various activities in the culture of sea bass in the Philippines and to identify its problems and needs.

Culture Practices

A number of fish farmers have attempted to culture sea bass in the Philippines using various methods and practices, such as the 'put and take' method in brackishwater ponds and impoundments, cage culture in bays and lagoons, and even in freshwater environments such as ricefields, ponds, lakes and reservoirs. These practices, however, are mostly done as a hobby, for recreation and primarily for food and livelihood. Examples of these follow.

Iloilo Province

BAROTAG NUEVOC

In one of the ponds in this town, sea bass fingerlings and postfingerlings are collected from the wild, purchased, or allowed to enter the ponds through the manipulation of the gates. The stocking density is unknown and the fish are of various sizes. The fish are fed with any kind of fish that are taken from the canal system of the ponds but mostly tilapia. Small shrimps and fish are allowed to enter the ponds and thus serve as food for the sea bass. Harvest is done by hook and line, cast netting and seining. A complete harvest is not done.

In the same town, a few fish farmers and agricultural farmers collect fingerlings from the sea and hold them in net cages installed in deeper portions of the ricefields. Some stock them in ponds utilising fresh water (zero salinity) coming from the irrigation system of the ricefields. It is interesting to note that proper acclimatisation from salt water to fresh water is not done systematically but the fish survive. These are grown to a size of from about 200 g to a few kilograms then sold to restaurants or in markets. Fresh fish are given as food.

VILLA, ILOILO CITY

Milkfish farmers culture the sea bass in their fish ponds as a secondary crop. Ponds near the river are used, where the gates are opened to allow sea bass fingerlings to enter. The fish are then allowed to grow in ponds together with milkfish. After about a month, a bamboo screen in installed in the gate with 1 cm mesh. The gate is then sealed with mudblock to approximately 30 cm to allow the ebb and flow of the water without the ponds being completely drained during low tide. This way, small fish and shrimp enter the pond and serve as food for the sea bass. Harvest is done after 3–4 months, together with milkfish. However, some unfortunate incidents may happen when the fish farmers

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forget that sea bass is a predatory species, and many of the milkfish provided food for the sea bass. The harvest may yield very few milkfish. When adequate sea bass fingerlings enter the ponds, the fish farmers don't mind the loss of the milkfish because the sea bass usually fetch a better price.

ZARRAGA

In one area in this town, one fish farmer appears to have a certain degree of success in his sea bass culture in ponds. He has a total of 32 ha of ponds devoted to sea bass plus a 2 ha pond as a sea bass nursery. His practice was originally similar to that described for Villa, Iloilo City, where he could harvest several tonnes of 500–800-g sea bass. More recently, he reserved a pond for tilapia close to his piggery pens. The wastes from the piggery are washed into the tilapia pond and tilapia grow very well at high density. Because the tilapia density is high, collection of the fish is easy and he seines the tilapia regularly to feed to the sea bass. The pond is stocked with sea bass at the rate of 1500/ha. About 100–150 kg of tilapia are seined once or twice per week. The sea bass feed also on whatever food is available in the pond. Sometimes a supplemental feed is provided, composed of rice bran, winged bean meal and trash fish.

The water depth in ponds is maintained at 50–80 cm and 0-10‰ salinity. Pesticides are applied in the ponds before stocking and fertilised with pig manure.

The source of the sea bass seed is either from the wild or from hatcheries which are stocked at about 1 cm. The survival is not yet very consistent, being between 25 and 60%. The fish are harvested by means of a gillnet so that it is selective and catches only the size that commands the best price in the market. The markets are hotels and restaurants for which the fish farmer harvests no more than 450 kg. The supply is kept at this level to maintain the market price.

Negros Occidental, Batangas and Bulacan

The sea bass culture techniques used in these provinces are similar, having adapted the techniques developed by research institutions. The combination of tilapia with sea bass at a stocking rate of 1500 to 2500 sea bass/ha and sea bass:tilapia ratio of 1:0 to 1:15 is the main technique used. One or two operators use the practice in Thailand which was modified by Banno and Amar (1985).

Attempts to Culture Sea Bass in Other Provinces

In Guiuan, Samar, where *Epinephelus* sp. is being cultured in cages for experimental purposes, cage culture of sea bass was also tried. The supply of sea bass fingerlings, however, became limited as did the trash fish for which sea bass competed with grouper for food. The study was therefore abandoned. A report from Puerto Princesa in Palawan also mentioned an attempt to culture sea bass in ricefields, but the method tested was not identified (Conlu, A., Bureau of Fisheries and Aquatic Resources, Puerto Princesa, Palawan, Philippines). A few years ago, two lakes in the island of Luzon were stocked with sea bass. These are the Laguna Lake in the province of Laguna and the Paoay Lake in the province of Ilocos Norte. There is no information available on the success or failure of this stocking.

The above practices indicate the crude methods of sea bass culture being used or attempted in a number of places in the Philippines. These are indicative of the acceptability of sea bass as a cultured fish. The lack of efficient and effective culture techniques, however, has limited their success. In view of this, the Brackishwater Aquaculture Center (BAC) initiated a program on sea bass in 1981 and the program continues. The work focuses mainly on the effect of various food types and stocking densities of sea bass on the growth, survival and production, use of sea bass as a biological control for undesirable fish species in brackishwater ponds, and development of artificial feeds for sea bass larvae and for juveniles. Attempts to simplify the techniques of spawning, larval rearing and production of larval food are also on-going.

At SEAFDEC-AQD, pond culture of sea bass utilising or modifying the technique used in Thailand, was tested. Some of the work done included the polyculture of sea bass and tilapia adapting the Thai method using 2000 tilapia broodstock at a sex ratio of 1:1, followed 2 months later by sea bass juveniles at a stocking rate of 3000–6000/ha (Sirikul 1982). Banno and Amar (1985) cultured sea bass in combination with tilapia and milkfish at different stocking combinations and concluded that the combination of 5000 sea bass, 4000 tilapia and 1500 milkfish obtained the highest net income.

Conclusion

The culture of sea bass in the Philippines has been attracting the aquaculture industry, but the lack of established techniques in pond grow-out prompted fish farmers to try methods that are available or practices that they themselves developed. However, because of the carnivorous nature of sea bass, and because the fish farmers are still using the culture methods for milkfish, the methods employed are not suitable for sea bass, and thus growth, survival and production are very low. Because of this, a number of fish farmers who started culturing sea bass in their ponds stopped temporarily. One other problem that could cause the decline in the interest in sea bass culture is the lack of established techniques for juvenile production close to the same sizes. This is very important because as soon as sea

bass fingerlings of varying sizes are stocked, cannibalism is encouraged and therefore mortality is high.

The need, therefore, for an established technique for the pond grow-out of sea bass and the need to develop methods for juvenile production are two very important areas requiring immediate attention to promote sea bass aquaculture in the Philippines.

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Status of Sea Bass *(Lates calcarifer)* Culture in Singapore

Leslie Cheong and Lee Yeng*

THE aquaculture industry in Singapore is presently focused on the culture of marine foodfish, mainly sea bass *(Lates calcarifer)*, estuarine grouper (*Epinephelus tauvina*), golden snapper *(Lutjanus johni*), mangrove crab (*Scylla serrata*), banana prawns (*Penaeus merquiensis*) and green mussels (*Perna viridis*). These are cultured in floating netcages/rafts and, in the case of prawns, also in brackishwater ponds.

There are 64 floating netcages/rafts, covering 33 ha, located at various designated areas along the west and east Johore Strait. Onshore there are 21 brackishwater ponds, covering 225 ha, located along the northern coast of the main island and on the northern island of Pulau Ubin.

In 1985 total aquaculture production from the netcages/rafts and ponds was 1284 t valued at ex-farm S$8.8 million. Sea bass production accounted for 13% of the production in terms of quantity (i.e. 169 t) and 20% in terms of value (i.e. S$1.8 million).

Development of floating netcage/raft culture was only intensified in mid 1981 when the government implemented a marine foodfish-farming scheme on floating netcage/raft culture. Since then there has been increasing consumer demand for live seafood served in restaurants, with prawns, groupers and sea bass being the most popular items.

Research and development studies on aquaculture are conducted by the Primary Production Department of the Ministry of National Development of Singapore. Investigations on marine and brackishwater fish culture are carried out by the Department's Marine Aquaculture Section at Changi Point.

Culture

Sea bass production of 169 t accounts for almost 50% of total finfish production from aquaculture. The fry/fingerlings are imported from hatcheries in Thailand. Those of other marine finfish, obtained from wild catches, are also imported from neighbouring countries. In 1985, a total of 7.8 million fry/fingerling was imported, with sea bass accounting for 32% of the total.

The fish are raised in net cages, initially in happa nets of 8 mm# at 150/m^2 and eventually in polyethylene nets of 25.4 mm# at 40/m^2. Total culture period is 8 months with growth from 2 g to 700 g market size. Annual yield is 36.75 kg/m^2 effective productive area. Commercial production averages 15 t/ha/year. (Water space of entire farm is included in calculation.)

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Table 1. Summary of management procedures and biodata of sea bass culture in floating netcages in Singapore.

Stage	Net type mm#	Size of Fish Wt(g)	TL(*cm*)	Density no./m^2	no./m^3	Culture period (days)	Survival (%)
Nursery							
a) happa	happa; 8	2–5	5	150	100	30	50
b) early nursery	a) happa; 8 or b) polyethylene; 9.5	20	11–12	70	40–50	45	70
c) late nursery	polyethylene; 9.5	100	20	50	33	60	85
Production							
d) grow-out	polyethylene; 25.4	300	30	40	27	105	85
e) at harvest	—	700	38–40	35	23	—	—

A summary of the management procedure and biodata of sea bass culture in floating net cages are given in Table 1.

Breeding

Successful breeding of sea bass has been achieved in Singapore. The technique, based on that developed in Thailand, is adapted for both onshore as well as offshore use. There are two farmers in the process of establishing floating sea bass hatcheries and nurseries at their net cage farms.

Sea bass brooders are raised from fingerlings to sexual maturity in floating net cages. Natural spawning of the fish, achieved either through hormonal inducement or environmental manipulation, is preferred over manual stripping.

The larvae metamorphose to fry at around day 19–20, and survival from hatching to metamorphosis averages around 38%.

During the nursery period frequent grading once every 5–7 days is necessary to reduce mortality due to cannibalism. Survival rate from fry to fingerling (20–30 mm TL) is about 40%.

A summary of the sea bass breeding procedure and biodata of the operation are given in Table 2.

Table 2. Summary of seabass breeding and biodata in Singapore.

I Broodstock

1. Water conditions: 28–31°C; 27–31‰
2. Method of rearing
   water transparency in floating netcages at sea — 1.5–2.5 m
3.

Stocking Wt(g)	Biomass density (kg/m^2)	Net dimensions (m)
2	0.15–0.25	2×2×2 depth
100–200	< 10	5×5×3 (depth)
3000		5×5×3 (depth)

4. Feeding — 2–3% body weight when fish exceeds 1 kg body wt.
   1–2% body weight during spawning season.
5. Sexual maturity
   Males: 2–2.5 years
   Females: 3–4 years
6. Spawning season
   May to October
7. Spawning method:

7.1 Size of spawners used:

	Age	Body wt (kg)
Males	3–5	2.0–7.5
Females	3–7	3.0–12.0

7.2 Egg Size: mean diameter 0.45 mm

7.3 Induced spawning:

Hormone	*Dosage*	*Remarks*
LH–RHa	♀: 6–7.5 μg/kg ♂: 6–40 μg/kg	actual dosage depends on maturation
HCG	♀: 40–250 IU/kg ♂: 30–IU/kg	condition of spawner

7.4 Stocking: 9 spawners/$40m^3$ tank
or 2 spawners/$10m^3$ tank
@ 1♀ : 1♂
or 1♀ : 2♂

7.5 Spawning: (typical pattern)

Day after hormonal injection	No. of eggs/female (million/female)	Remarks
0 (1st night)	0.28 or less	usually not fertilised
1	0.76–2.12	eggs are
2	$\bar{x}$ = 1.36	better quality

(Continued)

3	0.76–2.12 $\bar{x} = 1.36$	than those spawned on Days 4 & 5. Mean of buoyant eggs = 70.8%
4 5	0–0.22 $\bar{x}$ = 0.09	Mean % of buoyant egg = 37.2%

7.6 Description of fertilised eggs and hatching:

egg diameter	0.80–0.85 mm; $\bar{x}$ = 0.82 mm
oil globule diameter	0.25–0.27 mm
1st hatching	15.5 h after fertilisation
complete hatching	16–17 h @ 27–28°C

II Larva

1. Stocking density in culture tank:

Tank capacity (m^3)	Egg Density (no./m^3)
5	20,000–30,000
40	10,000–15,000

2. Time of transfer (to culture tank):
   1 hour before hatching.

3. Water conditions:
   Temperature: 26–30°C
   Salinity: 26–31‰

4. Water change:

Age of larva	*Water change*
0–2	no water change
3–5	20% daily
4–11	30% daily
12 onwards	50% daily

5. Growth and feeding regime:

Age (*Days after hatching*)	Total length of larva (*mm*)	Food	Remarks
0	1.60	—	*Chlorella/Tetraselmis* added to tank from Day 1–15.
2 (late)	2.50	rotifers at 2–3/ml	
3	2.60	rotifer density at 3–5/ml from Day 3–10	
10	3.5–4.0		
11	4.5	1. rotifer @5–10/ml from Day 11–15 2. *Artemia* nauplii @ <0.2/ml from day 11–12	
12	4.7		
13	4.8	*Artemia* nauplii @ 0.5–1.0/ml from Day 13–20	
18	8.0 (larger larvae	*Moina* @ 0.10–0.15/ml from Day 18–20	
19			Larvae metamorphose at Day 19–20.

20	8–9

6. Survival:
   in 5 m^3 tanks 13.7–75.0%; $\bar{x}$ = 41.7%
   in 40 m^3 tanks 20.7–64.7%; $\bar{x}$ = 35.5%

III Fry/Fingerlings

1. Management:

Age	Fish size *(mm)*	Density *(no./m³)*	Food/Remarks
20–25	< 10 (fry)	5000	*Artemia* nauplii and *Moina*.
20–35	10–15	4000	*Moina* and minced meat of trashfish or *Acetes*).
30–50	15–25	2000	weaned to minced meat.
45–60	>25	2000	sent to the sea for stocking in floating netcages (as reported by commercial farmer)

2. Survival: 40% from fry to juvenile.

Nutrition

Presently the cultured sea bass are fed on trash fish, which consists predominantly of small anchovy (*Stolephorus commersonii*), clupeids (*Sardinella fimbriata, Ilisha melastoma*) and euphausids (*Acetes* sp.). Feed conversion ratio (FCR) of 4.5:1 was obtained.

Weaning studies have been conducted on the sea bass. The fingerlings can be converted to dry diet either through gradual replacement of the trash fish or semi-moist pelleted feed binder mash with dry feed or direct replacement with dry feed. With the latter, conversion to feeding on dry feed is considerably faster. The fish can also be converted to feeding on semi-moist diet and can revert to feeding on trash fish and vice-versa — a feature which would be useful to the farmer whenever shortages in trash fish supply occur. Since the semi-moist pellets can be produced by a simple extruder on-farm, this method offers the farmer a practical alternative to feeding the fish with trash fish, until such time as dry pellets are available commercially. Results of the various weaning trials carried out to date are summarised in Table 2.

The same feed formulation used for groupers for dry pellet preparation is being used in feeding trials on the sea bass. The local source of fishmeal is found to be more acceptable by the fish than those from Thailand and Norway.

It was also found that dietary water content (7–32%) did not significantly affect growth and survival and only marginally affected food conversion efficiency.

Disease

Disease studies on sea bass have been mainly confined to case studies and sanitisation of imported fingerlings.

Protozoans are found to be the single most important group of pathogens in marine-farmed fish. Sea bass fry/fingerlings are particularly susceptible to infection by *Cryptocaryon irritans* and a 'wasting disease' of long duration is usually noted. Other protozoan pathogens are *Brooklynella* sp. and *Trichodina* sp. Infection by the crustacean *Nerocila* sp. is encountered in fry held in floating nurseries.

The only disease of proven viral aetiology in Singapore is lymphocystis disease and sea bass appear to be the only locally maricultured fish that is susceptible. This virus has been demonstrated to be infectious and water-transmissible.

Sanitisation of imported fingerlings is carried out to reduce the parasite and pathogen load on the fish and to minimise the danger of mortality arising from handling stress. Pre-shipment sanitisation requires the fish agent to treat the fingerling for 1 hour with acriflavin at 10 ppm prior to despatch. Trans-shipment sanitisation treatment involves the addition of nitrofurazone at 10 ppm to the packing water. On-farm sanitisation involves treating the fingerlings after landing with formalin at 100 ppm for 1 hour and then with nitrofurazone at 30 ppm for 4 hours. A medicated diet of oxytetracycline at 0.5 g/kg feed could be given daily for 7 days as a prophylaxis. The combined treatment as described increases survival by as much as 30%, depending on initial fish condition when packed and packing condition.

Sea Bass *(Lates calcarifer)* Cage Culture Research in Malaysia

Hussin Mat Ali*

CAGE culture of coastal finfish in Malaysia was started in 1973 but the development is still difficult to predict. Without further reductions in production costs, it will be difficult to achieve a major production increase at present price levels.

Lates calcarifer (sea bass), *Epinephelus tauvina* (grouper), *Lutianus argentimaculatus* (snapper) and *Lutianus malabricus* (red snapper) are among the cultured species. However, sea bass is commercially one of the most important fish species and is a highly esteemed delicacy in Malaysia. Because of this Malaysia initiated in 1976 production experiments on the sea bass in cage culture at Setiu Lagoon, Terengganu. It proved to be technically feasible and gave rise to ideas that this method of marine fish farming could be an activity to supplement the fisherman's income. In line with this objective, subsidies, training and technical advice were given to interested fishermen. Nevertheless the development of this project was slowed by the uncertainty of seed supply from the wild (Azlan 1982). But, this problem has not deterred the Fisheries Division objectives and other interested personnel from constructing net cages when alternative seed supplies can be found from Thailand. As a result, there are now many net cages established, especially in the west coast of Peninsular Malaysia.

Because the seed supply from the wild as well as from Thailand is inadequate, uncertain and expensive, it has been suggested that the breeding biology of the fish should be investigated with the aim of mass production under controlled environments. Research on sea bass production has been carried out at Penang Fisheries Research Institute since 1982, and at the same time Tanjong Demong Marine Fish/Prawn Hatchery in Terengganu (in the east coast of Peninsular Malaysia) was set up for sea bass fry mass production. Because of this, the development of net-cage culture in the east coast of Peninsular Malaysia now is quite advanced.

Site Selection

A suitable site will provide good growth conditions for cultured fish. Coastal areas, bays, straits, lagoons and estuaries, are among the suitable places for net cage culture. However factors like protection, water current, depth, dissolved oxygen, temperature, salinity and water pollution must be within a suitable range. For instance, the sites must be protected from strong wind or wave action. Water current at 20–50 cm/sec is considered to be optimum for water quality management in terms of water exchange to maintain dissolved oxygen (not less than 4–5 ppm) and excretory product removal, as well as minimising stress on the cultured fish.

Water depth will be determined by the depth of the net cage. For example, if the net cage is 2–3 m deep, water depth should be at least 5 m during low-water spring tide. Water salinity can vary depending upon the cultured fish. Sea bass can tolerate water salinity from 0 to 30‰ (Soesanto et al. 1985). Water salinity in coastal areas fluctuates due to the influence of fresh water from the rivers especially during the rainy season. This can cause the formation of stratification which is not preferred by stenohaline fish. Therefore euryhaline fish should be chosen.

Design and Construction of Net Cage

Floating net cages can be constructed in different sizes and designs, as well as material, depending on ease of handling, availability of materials, price and other factors.

Generally, the raft measurement is 7 × 7 m with four cages 3 × 3 m inner dimension. The cages may vary from 1.5–5 m deep depending on the water depth where the net cages are placed. Rafts can be made of wood or bamboo. Although bamboo is cheaper, it can last for only about a year, while wood frame can last for about 18–42 months (Soesanto et al. 1985).

Floats constructed of polystyrofoam or plastic drums were normally used by the fish farmers. Only nine polystyrofoam floats measuring 30 × 60 × 120 cm are needed for a raft, tied along the side of the cage and parallel to the water current to minimise the risk to the floats due to water current and wave action. Eighteen polysytrofoam floats measuring 30 × 60 × 60 cm are needed to construct a cage. This type of construction was very suitable for sheltered areas. As mentioned

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above, the use of plastic drums as floats is also possible but the numbers needed for a cage are more (50–60 floats with 22.7-l capacity).

Anchors are needed to ensure the raft will not drift away. The anchors can be constructed from cast-iron or cement blocks weighing 10–30 kg. Every raft has four anchors using ropes 18 mm diam for strength. The length should be 3–5 times water depth during high tide.

Polyethylene nets are usually used for cage culture because it is very strong and hardy, easily available, cheap and long-lasting. The size of the net can differ depending on the size of the cage and also water depth. For example, in Penang the size of the net is 1.83 × 2.13 × 1.42 m but in Kuala Setiu, Terengganu, the size is 3 × 3 × 3 m (deep).

Nets are divided into two categories: The *nursing net-cage* is also known as 'hapa.' There are two types of nursing net cage, one is with 8 mm mesh-size, used to rear those fish fry measuring 10–25 cm. 'Hapa' is usually smaller in size compared to production net-cage, the normal size measurement for first stage fry being < 10 cm is 2.5 × 1.2 m and constructed from nylon. 'Hapa' constructed for the second stage of nursing are usually made of polyethylene 12.5–25 mm mesh-size measuring 3 × 3 × 3 m. The *production net* is used to culture fish to marketable size: the mesh size can be in the range 25–50 mm. Normally the net cages used on the east coast of Peninsular Malaysia measure 3 × 3 × 3 m and are made of polyethylene net of 15–48 ply or more.

Cage Culture Procedure

Stocking Rate

Stocking rate for net cage culture depends on the fish size and location of the net cage. Fry (5–10 cm) were initially reared in 'hapa' at a rate of 100–150 pieces/m^2 of water surface or approximately 500 pieces in a 'hapa' measuring 2.5 × 1.2 × 1.2 m.

After 1 month the fry reached 12–15 cm with about 10% mortality rate. The remainder were selected then transferred into another nursery cage of 3 × 3 × 3 m at a rate of 40–45 pieces/m^2, approximately 400 pieces each cage for another 60–90 days and another 10% mortality rate is expected. By then all the remaining fish were transferred into a 3 × 3 × 3 m production net-cage for the rest of the rearing period which varies from 3 to 6 months depending on demands for marketable size fish as well as availability of another batch of fry supply for restocking.

Within 6–10 months culture period (from initial stocking date until harvesting), the fish will attain a body weight of 600–1000 g or an average of 800 g. However, factors like growth conditions, quality and quantity of feed as well as type of cage management will positively affect the growth rate and therefore close attention is necessary.

Feed and Feeding

The use of trash fish for feeding has been widely done and it can be said that all fish farmers are using trash fish as feed due to the fact that it costs less than formulated feed.

The amount of feed needed to be given depends on the size of fish. At the initial growth and juvenile stage, feed should be given 2–3 times/day at 20–40% body weight. As the fish grow until it reaches marketable size, the amount of feed needed becomes less (7–12% body weight). They should be fed twice daily between 0700 and 0900 hours and 1600–1700 hours.

Problems

Problems faced by the fish farmers usually differ according to place, time, fish species cultured, also the economical, social and knowledge status of the fish farmer.

For fish farmers rearing fishes in floating cages, problems faced are similar to those general problems faced in aquaculture activities. Ong (1985) has categorised the problems as follows.

Site

Suitable sites for brackishwater or marine aquaculture in Malaysia are very limited due to natural conditions. Thus, it is very difficult to find a sheltered area, free from strong wind, big waves and effects of fresh water. The last factor usually occurs in the east coast of Peninsular Malaysia especially during the annual monsoon season, thus proper site selection and feasibility studies are essential prior to the implementation of any brackishwater cage culture project.

Biological

Feeding Trash fish or low-grade fish are not easily available at all culture sites and prices are also on the increase. When more than enough fry can be produced in the hatchery, the expansion of marine fish culture will depend on the supply of trash fish or low grade fish available for use as fish feed. For example, the trash fish landing in Peninsular Malaysia totalled 150 454 t in 1979 and assuming that all the trash fish is used for the culture of marine carnivorous finfish, and by taking the conversion ratio of 10:1, the total production from the aquaculture of these species is estimated at most 15 000 t (Ong 1983).

Fry supply The breeding technology of sea bass is only just beginning on a commercial scale in Malaysia and thus the limited supply of fry is a major problem.

Natural enemies This includes predation among themselves and diseases which are sometimes caused by the infectious agents and non-infectious agents such

as malnutrition due to a low quality feed (spoiled trash fish).

Other Constraints

Lack of adequate financing and appropriate credit facilities are major constraints in the development of aquaculture in many countries including Malaysia. As this is a new type of enterprise insofar as the financing institutions are concerned, there is often considerable reluctance to extend support before large-scale commercial development occurs. Other problems include low consumer demand for sea bass in the local market due to high prices (compared with other fish), which makes the sea bass unaffordable to a large group of consumers.

Economics of Cage Culture

The economic study of cage culture was based on the 1984 achievement of a fisherman in Kuala Semerak, Kelantan (in the east coast of Peninsular Malaysia), who has operated the net cage culture of sea bass as a part-time job to supplement his income.

Approximately 4000 sea bass fry (7–10 cm) were obtained from Thailand at a price of M $1.40 each, and reared in four net cages of 3 × 3 × 3 m for about 9 months. About 2168 kg total yield was harvested with an average 800 g body weight and were sold at M $8.30/kg. The total production cost per kilogram was M $5.63.

Discussion

Although these figures are from four cages, cage culture does appear to be a viable activity to supplement one's income. But the figures given here do not necessarily reflect the situation with all cage culture activities in Malaysia. This is due to such factors as marketability, management and also environmental factors. These will affect the final income of the fish farmers. Thus Nik Wahab (1982) recorded the average income for 16 net cages (4 rafts) as M $625/month whereas Soesanto et al. (1985) noted that the income for 4 net cages (one raft) will be M $397.42 per month and by simple multiplication this will be M $1589.68 per month for 16 net cages. This huge difference in income is due to the different cost of buying fish fry at M $1.20-2.00 each and also market price of M $7.00-$10.00/kg. This is due to the fact that the experiments were carried out at different times and places.

Recently the market price for sea bass has gone down to between M $6.00–$7.00/kg but the cost of construction, fish feed and management has increased. The development of net cage culture, therefore, has been slowed especially in the east coast of Peninsular Malaysia. Due to the lower level of income and high capital investment, fish farmers, who are usually ex-fishermen, or their families cannot afford to face this management risk.

To help the fish farmers to overcome the high cost of buying the fry, thus giving them a higher income from the culture, the Fisheries Department is helping by encouraging them to rear the fry sold by the government hatchery at 20 cents for 2.5-cm fry which are produced locally. Usually after 2 months the fry will have reached the average size of 10 cm with approximately 80% survival rate. With this method, the farmers can save about 80% from the cost of fish fry or save 44–54% from the variable cost because 55–56% of the variable cost is used for buying fish fry, 20–30% for feed, 5–10% for labour and the rest for other expenditure.

Conclusion

Efforts by the government, especially the Fisheries Department, to overcome the shortage of sea bass fry, through the establishment of fish and prawn hatcheries, is expected to bring about an expansion in small-scale brackishwater/marine aquaculture.

The department also has an extension program to provide advice and training to help the farmers with fish culture problems. With all these efforts, it is hoped that the marine/brackishwater aquaculture will expand in the near future, and those areas found suitable for cage culture will be fully utilised.

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Review of the Sea Bass *(Lates calcarifer)* Fishery in Burma

Win Htin*

SEA BASS, *Lates calcarifer,* locally known as 'Ka-ka-dit,' commands a premium price in Burma. However, very little is known about its fishery and biology, although a number of systematic studies have been carried out (Than Tin 1972; Hnin Yu Lwin 1972; Khin Myat Htwe 1983; Myint Myint Than 1983; Esther Kyaw Soe 1984; Kyaw Kyaw Htay 1985). This species is an economically important food fish in the countries of the tropical and subtropical areas of the western Pacific and Indian Ocean (Rabanal and Soesanto 1982). In Thailand, for example, the selling price at the fish farm was between 60 and 65 Baht (US$3.00 to 3.50) in 1980 (Sungkasem 1982). The commercialisation of the species was made possible initially by the successful artificial propagation of *L. calcarifer* in 1975 in Thailand (Sirikul 1982).

Burma, with a long coastline of 2826 km, has many rivers forming a network of tributaries, estuaries and mangroves estimated at 520 000 ha (Win Htin and Nyan Taw 1985). This coastal region has great potential for the development of a capture fishery as well as a culture fishery for sea bass.

Capture Fishery

Production of sea bass in the Irrawaddy delta is mainly from the leasable fishery. The Department of Fisheries recently initiated an inland fishery stock assessment study.

Culture Fishery

Lates calcarifer is considered an undesirable predatory fish in the aquaculture business in Burma.

A study to grow sea bass in an experimental brackishwater shrimp farm at Naukme in Bogale Township (Irrawaddy Delta) was initiated recently with fingerlings collected from natural waters.

The experiment was carried out under the management of People's Pearl and Fisheries Corporation. The 28-ha farm is approximately 2 km from the seashore, thus making availability of brackishwater easier. The farm has 20 ponds ranging from 0.25 to 2.5 ha. The main purposes of the farm are the culture of brackish-water shrimp *Penaeus monodon,* with seed collected from natural waters, and for the training of aquaculturists.

Culture Pond

The pond used in the experiment was a 2.5-ha production pond. The depth of the pond varied from 1 to 1.5 m. The pond has two 1 m-wide concrete gates for water intake and drainage. The gate has screens to prevent predatory fish entering and culture fish from escaping. The bamboo screens had gaps between the 0.5-cm sticks of 0.5 cm.

Pond Water Management

Although the pond had inlet and outlet gates, only the inlet gate was used due to high siltation. Pond water was circulated only during high tide. During neap tide the gate was closed preventing water exchange between pond and river water. Physical and chemical parameters of pond water, such as salinity, pH, dissolved oxygen, temperature, transparency, and water depth were recorded weekly.

Feed and Feeding

The most inexpensive trash fish available were *Coilia dussumieri, Settipinna tatty, Ilisha elongata* and *Anchoviella commersoni.* They were available only during high tide period. During neap tide, because of difficulties in using small-scale net traps which utilise tidal force, the trash fish were hard to obtain. Therefore feed could be provided only during high-tide days. The trash fish were chopped into small pieces and distributed near the sluice gate. Five per cent of calculated fish body weight of feed was given during feeding days.

Fingerlings

The fingerlings (total of 8258) were obtained from artisanal fishermen, who used the conical bag net (U Khin 1948). Small fingerlings (2–5 cm) were caught either with cast net or scoop net. The fingerlings weighing 32–50 g were acclimatised before being introduced into the culture pond.

*Brackishwater Shrimp Farm, Bogale, Burma.

Results

The first harvest was carried out in the 9th month, and the final harvest at 14 months.

At the first harvest only large specimens were selectively harvested and a production of 133 kg was obtained. At the final harvest, 427 kg was collected, for a total of 560 kg (224 kg/ha); 1006 fish were caught ranging in length from 30–45 cm, and weighing 0.38–1.5 kg. The survival rate was about 13%.

The yield achieved in the present study is low compared to other studies (e.g. Rabanal and Soesanto 1982; Sirikul 1982), probably due to the many difficulties experienced during the study. There were many constraints, such as inexperience in brackishwater pond management, availability and collection of fry, and in obtaining feed. This experiment could, nevertheless, be a useful first step in the further development of sea bass culture in Burma.

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Status of Sea Bass *(Lates calcarifer)* Culture In India

P.S.B.R. James and R. Marichamy*

CULTURE of carnivorous fish such as *Lates calcarifer* has gained importance in Southeast Asian countries in recent years. The giant perch or sea bass (locally known as 'bhekti') inhabits the brackishwater environment and is both eurythermal and euryhaline. Except in the Sunderbans area of West Bengal, and to some extent in other brackishwater areas along the east coast, no serious efforts for the culture of sea bass on a commercial scale are being made at present. In the traditional fisheries cultivation method of 'trapping and holding,' complete reliance is placed on the tidal influx to bring larvae and juveniles of this valuable species into the impoundment. Pillay (1958) and Hora and Nair (1944) have described the culture practices of the fish in brackishwater impoundments of the deltaic area of West Bengal.

A wealth of information on the biology and ecology of this fish is given by Jones and Sujansingani (1954), Jhingran et al. (1963), Jhingran and Natarajan (1966, 1969) and Patnaik and Jena (1976). The distribution pattern of different life stages in different ecosystems, such as coastal waters, estuaries, lagoons, brackish-waters, and even in fresh water, to aid in seed prospecting and procurement of breeders from the wild population is also known (De 1971; Ghosh 1973). Similarly, the growth pattern and reproduction of this species have been studied by Naidu (1939), Chacko (1956), Pillay (1954), Rao (1964) and Kowtal (1977). The present account also embodies the results of *Lates* culture carried out in a coastal pond at Tuticorin along the southeast coast of India.

Biology

Length-Weight Relationship

Ganguly et al. (1959) have given a detailed report on the length-weight relationship in a natural population of *L. calcarifer*, and concluded that the relationship does not differ significantly from Spencer's cubic law. De (1971) studied the length-weight relationship of postlarvae, fry and fingerlings of this species. The study revealed a strong positive correlation of these two parameters and obtained the equations for post-larvae (10–15 mm) as Log W = 6.41506 + 3.62342 Log L; for fry (16–45 mm) as Log W = 6.83589 + 3.188958 Log L; and for fingerling (50–200 mm) as Log W = 6.70072 + 3.22692 Log L. Based on the regression lines and length–weight relationship curves at different stages drawn from calculated values, the author indicated fastest growth when it feeds on zooplankton at postlarval stage. The growth rate gradually retarded at fry and fingerling stage when it feeds on insects and fishes respectively. The young ones and fry have been found to thrive well both in high and low salinity, being highly euryhaline.

Saha et al. (1978) analysed the interrelation between the growth of natural and controlled populations of *Lates* and found the total length–standard length relationship linear with a high regression coefficient for lower values in the control and natural groups and a lower regression coefficient for higher values in the control group. Patnaik and Jena (1976) have studied the length–weight relationship of this species based on 563 specimens regardless of sex, size and period of collection in the size range 24–1010 mm and 0.2 – 12 707 g and the relationship was found to be Log W = 2.9166 Log L – 4.70792.

Age and Growth

The size frequency of *L. calcarifer* is available for the period 1957–65 for the fishery of Chilka Lake. Jhingran and Natarajan (1969) have studied the average length of different age-groups by regression analysis. When modal values of sizes of constituent groups are plotted simultaneously, as many oblique rows as the age-groups are obtained. The authors followed the growth of species from young stages recruited to the fishery in February at size 162 mm and again in July–August at modal sizes 112–162 mm. The recruits reached an average length of 287 mm in 1 year and 492 mm in 2 years, 687 mm in 3 years and 799 mm in 4 years.

The fish generally grow to 300 mm and 500 g in 1 year. Mukhopadhyay and Karmakar (1981) observed that the growth of fish in 10 and 15‰ salinity to be equal but significantly different from the growth in other salinity levels. This range usually prevails in the sea bass of West Bengal during May–February and this period has been favourable for the faster growth of the

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species. The food intake is higher in the low-salinity range. The higher rate of feeding and growth at lower salinities are the advantageous conditions to be provided in the nursery stage of culture.

Alikunhi (1957) observed that sea bass grow to 450 mm in 1 year in fresh water. Hora and Pillay (1962) recorded an annual growth of 1.5–3 kg in a pond. The culture observations made by Ghosh (1971) indicated that the average growth in length was much faster in the first 3 months than during the subsequent period. The species attained an average length of 25.3 cm in the first year with a maximum of 50.7 cm in freshwater ponds at Kakdwip (West Bengal).

Food and Feeding Habits

Lates calcarifer is extremely predacious. It is a column feeder, with small fishes, shrimps, snails and worms being the important items of food. The species tends to be cannibalistic when food is scarce and if the pond is stocked with unequal size groups. Food and feeding habits of juveniles and adult *L. calcarifer* have been reported by Day (1878), Mookherjee et al. (1946), Menon (1948) and Pillay (1954). Chacko (1956) described this fish as highly carnivorous, feeding mainly on fishes such as *Mugil* spp., *Chanos chanos, Silago sihama, Elops indicus, Gobius, Stolephorous indicus, Spratelloides, Orizias, Aplocheilus* and on crustaceans (*Penaeus, Squilla, Acetes, Palaemon* and *Caridina*). The species also browses on rocks and consumes bivalves such as *Arca* and *Mytilus*. This perch ascends Godavari and Krishna rivers on the east coast of India to a distance of about 80 miles from the sea for feeding purposes. He further suggested that the species can be profitably used for culture in swamps and other weedy waters where there is abundant animal forage. De (1971) made a detailed study and gave indices of preponderance of food items in the gut contents of postlarvae (10–15 mm) *L. calcarifer*. Postlarvae are purely planktophagous, feeding on zooplankton and gradually switching over to entomophagous habit at the fry age. Fingerlings at the early stage prefer bigger insects and their nymphs, but gradually change to bigger crustaceans and fish. At this stage the species tends to be cannibalistic. Mukhopadhyay and Karmakar (1981) studied the effect of salinity on food intake, growth and conversion efficiency in juveniles of *L. calcarifer* and found higher food intake in 5–20‰ salinity range. The study revealed that the lower range of salinity is ideal for better metabolism of young fish. The diurnal variation in the feeding intensity has been established and the higher feeding rate observed during darker periods may be due to the predator dependence of nocturnal animals like shrimps and other crustaceans. The greater dependence on nocturnal prey requires the perch to increase its feeding activity during night.

Patnaik and Jena (1976) have given the composition of food items of *L. calcarifer* of different size groups. The planktonic forms of copepod nauplii and molluscan larvae constituted the food of young fish at 24–50 mm. The fish at 51–150 mm mainly consumed mysids, prawns and small fishes and bigger fish (above 150 mm) subsisted on fishes and prawns.

Migration

The migratory movements of young ones into estuaries, lagoons and brackishwaters have been observed by most of the workers as they appear to be the nursery grounds and offer scope for active feeding. Ghosh (1971) collected sea bass fry from Kulpi and Rajnagar in West Bengal situated 74 and 30 km respectively from the sea. Similarly, the adults ascend further into freshwater areas reaching the dams across the rivers. Chacko (1949) reported the occurrence of the fish from lower Anicut of Coleroon River. Chacko (1956) has also recorded the migration of this species in Godavari and Krishna rivers up to a distance of 80 miles from the sea. The species was reported (Anon 1951) to ascend about 130 km from the sea for feeding.

Spawning

The spawning season, breeding grounds and attainment of maturity of sea bass seem to vary according to the location. Generally, the fish spawns from January to August.

The gonads of *L. calcarifer* are strongly dimorphic and the sexuality of the species led Moore (1979) to the conclusion that it was a protandrous hermaphrodite. Based on the length-frequency study he noticed a dominant mode for mature males at 89.5 cm and a smaller mode for females at 101.5 cm and established sex ratio as 3.8:1 favouring males. Lack of sampling of large numbers of fish belonging to different size groups due to its high cost and non-availability at times are the limiting factors for the absence of adequate information on sex-ratio of the species in Indian waters. Hermaphroditism and indeterminate condition of the sex in young fish may also be the causes for lack of information in this area.

Jhingran and Natarajan (1969) determined the minimum size at first maturity of the species as 425 mm in year II. Alikunhi (1957) and Chacko (1956) found the size range of breeders from 50 to 60 cm and the breeders to occur close to the river mouths during the colder season. Patnaik and Jena (1976) encountered the smallest mature female at 700 mm and male at 505 mm (TL).

Naidu (1939) observed sea bass breeding in the Sunderbans in the winter season, where large numbers of young ones were seen in the pools and ditches on the sides of estuaries in April. Jhingran and Natarajan (1969) observed mature specimens during April–July and suggest two peaks of spawning: one in January-

March and the other during June–July. Rao (1964) and Shetty et al. (1965) on the basis of availability of ripe specimens and large numbers of fingerlings (60–80 mm) have inferred October–November to be the breeding period for Mahanadhi sea bass. De (1971) suggests the breeding season of *L. calcarifer* to be July–August from the occurrence of postlarvae (10–15 mm) in the vicinity of Junput in West Bengal. In Madras area, the breeding is reported to occur in the inshore areas at the mouths of estuaries (Anon 1951). Gopalakrishnan (1972) collected the fry of this species in good numbers from Kulpi on Hoogly River and Thakuran and Matlah rivers during May–October. Rao and Gopalakrishnan (1975) observed the fingerlings 50–70 mm long in the northern sector of Pulicat Lake in May–June. Patnaik and Jena (1976) recorded mature specimens during April–July and ripe fish as well as spent fish in the outer channel of Chilka Lake during May–June and advanced fry measuring 22–52 mm in the mouth area of the lake during July–September. They have estimated the fecundity of the species to be 0.76 million eggs/kg of fish at one spawning and the results are comparable to those of Dunstan (1959).

A number of workers (Chacko 1949, 1956; Jones and Sujansingani 1954; Jhingran et al. 1963; Jhingran and Natarajan 1969; and Patnaik and Jena 1976) have concluded that the species is catadromous, spawning and hatching taking place in the sea. The advanced fry and fingerlings move into the lake for feeding and growth. But this species migrates upstream for breeding in Thai waters and Smith (1945) assumed that the fish is anadromous. Rao (1964) suggests the possibility of *L. calcarifer* breeding at Hukitola Lake in Mahanadhi estuarine system in India. Based on the collection of ripe and oozing specimens of this species from Kaluparaghat area in the northern sector of Chilka Lake during May–June, Kowtal (1976, 1977) suggests the possiblity of this fish breeding in the lake beside the adjoining water of Bay of Bengal.

Early Life History

Mukhopadhyay and Verghese (1978) have described the techniques of collection and segregation of the fry of *L. calcarifer* with notes on identification of larvae. Ghosh (1973) gave useful aids for identification of the larvae and juveniles ranging between 6 and 69 mm. De (1971) in his detailed report on the biology of postlarvae and juvenile stages of *Lates* tabulated the morphomeristic features of different size groups and revealed easy distinguishing external characters for identification of postlarvae 10–15 mm, fry 16–45 mm and fingerlings up to 200 mm. The fry of *Lates* above 2 cm have a close resemblance to the adult in general body contour and other features, except in colour. The bands of black chromatophores extending between dorsal and ventral, rayed dorsal and anal and at caudal base are useful aids for field identification. The white stripe originating from the tip of the snout extending up to 1st dorsal on the head and the presence of preopercular spine are useful for field collection.

Information on the abundance and distribution of sea bass fry is better known from the east coast of India. Estuaries of the various river systems particularly the Hoogly-Matlah, Mahanadhi, Krishna, Godavari and the coastal lakes like Chilka and Pulicat and lagoons and tidal creeks are rich sources as they form nursery areas and ideal shelter for this species. Intertidal pools with grassy vegetation in Sunderbans have been identified by many earlier workers as the main source for collection of *Lates* seed. The fry gain entry into nursery areas of West Bengal along with the tide (Jhingran 1983). The distribution of this fry in Muthupet saline swamp has been reported by Chacko (1949). De (1971) recorded a swarm of postlarvae entering Junput Brackishwater Fish Farm at Contai, West Bengal, along with the high tide during July–August in a new moon period. They get nursed and reared there till the subsequent full moon tide occurs when they get caught.

Fry and fingerlings of *L. calcarifer* are collected by small meshed drag-nets and cast nets (Hora and Pillay 1962). Happa net is widely used for collection of fry at the end of the high tide. The spawn collection net is fixed against the receding tide in creeks. The collections are filtered through a tray of 2-mm mesh. *Lates* fry less than 6 mm will pass through this filter retaining the large specimens of other groups in the sieve. The scoop net collections contain fry of the size range 4–45 mm. The seed was abundant in the collections made at Kakdwip. The catch per net per hour in the happa net was 140 during May and the catch by shooting net was 167/net/hour during July (Mukhopadhyay and Verghese 1978). Ghosh (1971) made some observations on transportation and acclimatisation of sea bass fry from collection centres at Kulpi and Rajnagar to Kakdwip Farm in West Bengal and found that no mortality occurred when the collections were kept in enamel hundies. The fry are hardy and withstand transportation without oxygen for 2–3 hours. The system can be improved and more seeds can be packed in collapsible type of oxygenated polythene seed transportation bags now available. Studies on quantitative distribution of the seed in space and time for charting out potential grounds and for evolving suitable methods for collection of seed should be conducted for successful farming.

Culture

India possesses vast stretches of cultivable estuaries and brackishwater areas estimated by different authors at 1.4 to 2.02 million ha. The brackishwater fish culture practice has been in vogue for a long time in Kerala and West Bengal. In general, the aquaculture systems are categorised into extensive, semi-intensive

and intensive systems. The extensive system includes unselective stocking accomplished by the seed being carried in by the rising tides, holding them to grow, feeding on available natural food without any control over predators and harvesting them periodically. More recently, the Central Inland Fisheries Research Institute and Central Marine Fisheries Research Institute have started projects on culturing *L. calcarifer* on an experimental level under a semi-intensive system.

Due to the vagaries of nature, a dependable supply of seed from natural sources cannot often be ensured. Production of *Lates* seed by induced breeding and stripping may become practicable since possibilities for the collection of breeders from lakes are reported by several workers. The main constraint in the culture of the species is the availability of seed. However, till such time as induced breeding techniques are perfected for production of seed, the culture of *Lates* will have to depend on seed available in nature.

Methods of Culture and Review of Results

Lates calcarifer can be profitably cultured in ponds, net cages and pens. Most of the traditional culture practices in the country are made in ponds. In Thailand and Singapore rapid development of cage culture has taken place. The carnivorous fish are normally reared in floating cages as they need sufficient depth and flow of water.

Available information on the culture of this species is scarce, with little detail on survival or production rates. Information such as stocking rate, feeding practices, environmental monitoring and other farm management practices is lacking. Pillay (1954) observed sea bass fry that entered ponds at 2–5 cm size during rainy months attain a size of about 12.5 cm by October–November, attaining an average growth up to 25 cm in the second year. Better growth results are recorded in the culture of *Lates* in paddy fields in West Bengal. *Lates* entering the paddy fields in September at an average size of 12.9 cm was found to grow to 21.5 cm in October and 36.4 cm in November. This striking growth was attributed to the presence of forage fish as food (Pillay and Bose 1957). Another freshwater culture experiment conducted by Ghosh (1971) also indicated much faster growth in the first 3 months from a stocking size of 38–205 mm. The fish attained an average size of 253 mm in 1 year. Prior to stocking of *Lates*, the pond was already stocked with a variety of fish seeds to serve as forage fish. Jhingran (1977) recorded a gross production of 2759.5 kg/ha in 8 months by rearing *Lates* in feeder canals during the production phase. This was possible because of the surplus of natural food organisms like prawn fry and fish brought in by the tidal water.

This species is also cultured in sewage-fed ponds using *Tilapia* as forage fish by a team of workers in CIFRI Barrackpore. Prasadam et al. (1984) tried to culture this fish in pen and cage in lagoon system at Pulicat Lake, and found the fingerlings stocked at 142 mm/30 g in velon cages in September 1983 grew to 164 mm/339 g and 208 mm/496 g with survival rate of 50–55% in a period of 14 months.

The results of culture experiments carried out in coastal ponds at Tuticorin are presented in Table 1. The particulars of the culture site are described in Marichamy and Rajapackiyam (1982). The seeds for stocking are gathered from other ponds at the time of harvest of earlier experiments. Young *Lates* stocked at an average size of 217 mm in March 1983 have grown to 424 mm/878 g in a period of 15 months in the first experiment. In the subsequent experiment the stock released at 285 mm during September 1984 progressed to 472 mm/953 g in 17 months duration. The monthly average growth rate varied from 10 to 17 mm/20 g to 80 g in these size groups. The big fish were lost due to

Table 1. Results of experimental culture of *Lates calcarifer* in coastal ponds.

Size of pond(m)	Stock No.	Rate of stocking/ ha	Date of sampling	Size range *(mm)*	Average size *(mm)*	Wt. range *(g)*	Average wt.*(g)*	Average growth Size *(mm)*	Average growth Wt. *(mm/g)*	Overall average growth (%)	Survival rate
60×42	26	104	18.3.83	176–255	217.0	65–205	138.0	—	—		
			30.6.83	230–275	254.0	165–250	208.0	10.0	20.0		
			30.9.83	284–325	310.7	320–565	460.3	14.4	76.5		
			30.12.83	332–365	350.4	556–692	641.6	13.9	52.4		
			21.3.84	390–440	415.0	710–865	791.0	15.7	51.8		
			28.7.84	370–485	424.0	590–1350	875.0	12.5	44.4	12.5/44.4	77.0
60×42	44	176	18.9.84	235–340	285.0	110–385	225.0	—	—		
			27.12.84	270–375	326.4	166–468	338.7	12.4	34.1		
			28.3.85	338–440	393.3	615–866	734.0	17.0	80.4		
			25.6.85	385–470	418.0	680–1025	807.3	14.2	62.4		
			29.9.85	405–478	435.8	702–1040	846.1	12.0	41.7		
			26.12.85	446–482	469.0	780–1070	945.0	11.8	46.5		
			1.3.86	428–520	472.0	790–1200	953.4	10.5	41.3	10.5/41.3	45.5

poaching in the farm. The fish were fed with frozen trash fish at 10% body weight. The results were better than those obtained at Pulicat Lake in the cage culture system. The growth recorded by Dhebtaranon et al. (1979) on *Lates* in net cages was more or less similar to the present observation, but gain in weight was more in Thailand. When compared to brackishwater culture, the present results are lower, since the salinity in the pond was well above (35–54‰) the normal salinity of sea water during most of the period. It appears that low salinity and live food in the form of forage fish promotes the growth of *Lates* in culture system.

The present observations indicated that better water exchange in the culture site, particularly to maintain the salinity at least equivalent to open bay water around 33‰ and the supply of fresh trash fish obtained from commercial trawlers as food and stocking rate at 400/ha would be suitable conditions for increasing production.

Marketing and Commercial Aspects

A good demand exists for the fish as it is esteemed as a highly delicious fish and also fetches a fair price. The bulk of the catch is handled by intermediaries who sell either direct to consumers in retail markets or to markets where it is auctioned. From places where it is cultured, the catch is transported by a variety of means to consumer markets or storage establishments. Most of the collections are sent to Calcutta markets and sometimes preserved in ice for transportation to distant places.

Lates is cultured in freshwater paddy fields by private farmers in eastern India. Larger farms in Sunderbans area are organised by Central or State Fisheries departments and no organised hatchery for the species has been developed so far in the country.

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Management of Wildstocks

Utilisation and Wildstock Management of the Barramundi *(Lates calcarifer)* in the Northern Territory

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THE wildstock populations of barramundi (*Lates calcarifer*) in the Northern Territory are currently harvested by three distinct user groups: commercial fishermen, recreational fishermen, and traditional (aboriginal) users. Each of these groups has fishing rights in relation to the barramundi resource which must be considered when managing the fishery.

Commercial barramundi fishing appears to have been carried out since the establishment of permanent European settlement in the Northern Territory, although early commercial fishing was to supply local markets only. It is only during the last 30 years that the commercial barramundi fishery has developed to become a significant economic component of the Territory's economy. The landings and value figures provided in Table 1 give an indication of the worth of this fishery to the Territory over the last 10 years.

Table 1. Northern Territory barramundi fishery landings and value.

Year	Total landings (tonnes, live weight)	Value ($A '000)
1976–77	1163	1 361
1977–78	1089	1 504
1978–79	933	1 870
1979–80	690	1 272
1980–81	744	1 561
1981–82	858	1 925
1982–83	774	1 930
1983–84	633	1 628
1984–85	636	1 737
1985–86	573	1 671

While little detail is recorded on the historical extent of recreational fishing for this species in the Northern Territory, presumably there have been local anglers fishing the coastal regions and rivers close to areas of settlement for many years, if only as a means of supplementing their food supply. In recent years the amount and extent of recreational fishing activity has increased considerably, due in part to increased leisure time and earnings available to local residents and improved access to recreational fishing spots. Implementation of current government objectives, which calls for increasing economic diversification and development of the Northern Territory's resources, has also encouraged active growth of the recreational fishery, the promotion of barramundi fishing being part of a fairly extensive NT tourist industry promotion.

Traditional aboriginal fishermen have harvested barramundi around the coastal regions and in the freshwater rivers and billabongs of the Territory since long before European settlement here. Barramundi has been, and continues to be, a fairly important food source and totem figure to this group.

Utilisation of the Resource

Commercial Exploitation

In comparison to a recently observed growth in numbers of recreational barramundi fishermen in the Northern Territory, the last 5 years have seen a gradual decrease in the numbers of operators in the commercial fishery (Table 2). This decline in numbers has resulted from the implementation of management measures as discussed later.

Commercial fishermen in the Territory harvest barramundi using monofilament and multifilament gillnets of 150–200 mm mesh size. These nets are set in rivers, estuaries and along the coast and their length can vary from 100 to 1000 m, although in previous years some fishermen did use up to 4000 m of net at a time.

The fishermen set, check and clear the nets from outboard powered dinghies. Barramundi captured in the nets are taken by dinghy back to the main vessel or a land-based camp for filleting, packaging and freezing.

The greater proportion of this commercial catch is removed from coastal and estuarine waters around the Alligator, Mary, Daly, Roper and McArthur rivers (Fig. 1). Certain areas of the coastline are not open to

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Table 2. Northern Territory barramundi fishery landings, effort and CPUE.

Year	Total landings (whole weight)	Total fishery effort	CPUE *(kg/hmd)*	No. operators
1972	382.0	17.3	22.1	*
1973	431.3	21.0	20.5	*
1974	656.0	22.8	28.8	121
1975	432.3	15.7	27.5	79
1976	973.8	*	*	198
1977	1054.0	72.0	14.6	162
1978	820.0	95.9	8.6	165
1979	745.0	100.7	7.4	113
1980	531.7	71.6	7.4	107
1981	764.11	66.9	11.4	99
1982	856.1	95.4	9.0	81
1983	603.1	87.1	6.9	60
1984	617.1	71.6	8.6	49
1985	596.4	65.7	9.1	47

* Data not available.

fishermen because of access restrictions on land granted to Northern Territory aboriginal communities.

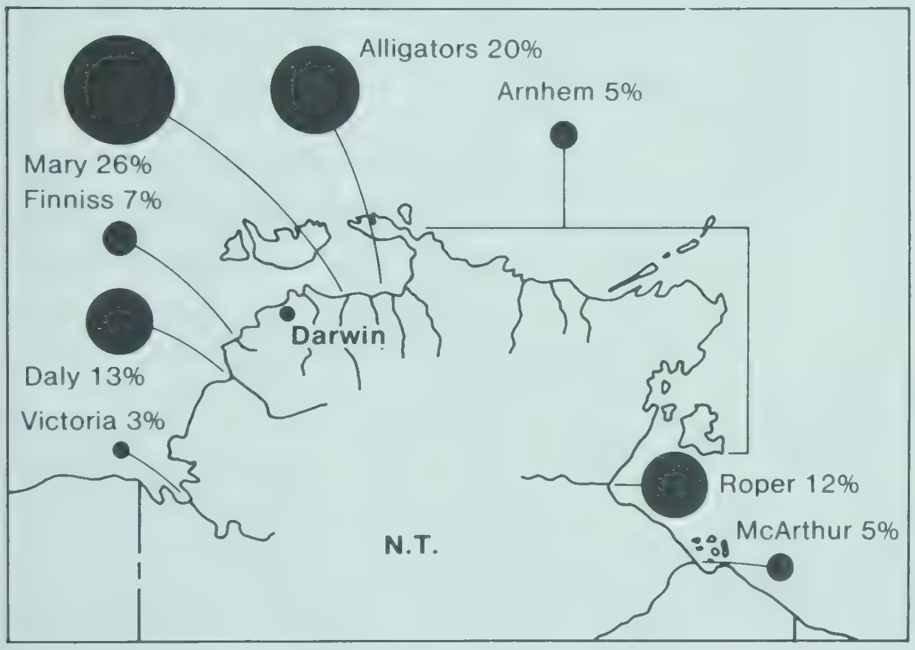

Fig. 1. Northern Territory barramundi fishery landings by river systems (mean 1972–84).

While some of the commercial barramundi catch is sold on the local Territory market, the majority is shipped to southern states for sale to the restaurant trade where it is a highly regarded and highly priced table fish. Average prices paid to fishermen for filleted barramundi have risen steadily from $0.65/kg in 1966–67 to $8.30/kg in 1986.

The Recreational Fishery

Recreational fishing for barramundi is a leisure activity participated in by an ever-increasing number of people. While the majority of anglers are local fishermen who live in the major population centres and travel to recreational fishing spots close to their home, a growing number are tourist anglers who travel to the Territory to catch a barramundi as part of their holiday experience.

Recreational fishermen catch barramundi primarily from small outboard-powered dinghies using rods and light monofilament lines with lures or bait. Most amateur fishing takes place in the fresh waters of the major river systems, their tributaries and billabongs, with the heaviest recreational pressure being applied to rivers close to Darwin (e.g. the Mary, Alligator and Daly systems).

While no accurate measure is yet available of the amount of barramundi caught by recreational fishermen in the NT, a survey undertaken in 1978–79 of the Mary/Alligator River systems indicated that amateurs caught approximately 80 t of barramundi during the 12 month survey period (Griffin 1982).

More recently (1984–86) estimates from continuing survey work conducted in this same region suggest that the number of recreational fishermen harvesting this resource has tripled in recent years and that this group may take as much barramundi as those commercial fishermen remaining in the fishery (Griffin unpublished data).

The Traditional Fishery

While barramundi has been traditionally harvested by aboriginal fishermen using spears and native fish traps, more recently fishing methods have changed. In most cases barramundi is now caught using handlines as a recreational fishing activity, or by setting small lengths of gillnet (up to 200 m) from aluminium dinghies, although fishermen no longer target on barramundi using this gear.

Barramundi taken by members of the various communities is used primarily to feed the inhabitants of their community, although in previous years several of the communities held commercial barramundi licences. The percentage of the total catch taken by traditional fishermen has not been measured but is estimated to be of such an insignificant portion that it is ignored when carrying out yield assessment modelling for the fishery.

Management of the Resource

As with many other fish populations, barramundi wildstocks in the NT are classed as a common property resource and as such the basic responsibility of fisheries managers is to manage the fishery in the interests of the NT community. When preparing management plans, due consideration must be given to the historical rights of the various user groups (commercial, recreational and traditional fishermen) to harvest this resource. Also management must be consistent with the aims of maximising the net economic benefits from the fishery whilst maintaining the long-term viability of population levels of the barramundi throughout its habitat.

Stock Assessment

To achieve these management aims it has been necessary to obtain estimates of what yield could be sustained by the fishery. Due to a lack of data on population parameters for this species, assessment of yield for the Northern Territory barramundi fishery was intially based on the surplus production model (Schaefer 1954) using detailed catch and effort data collected from the commercial fishery.

Early assessments of sustainable yield for the Territory barramundi population were based on combined commercial catch figures, treating the fishery as one stock. From these early assessments theoretical total levels of effort were determined and used as a guide for management. In 1983 these initial estimates of yield were modified slightly by use of the Fox surplus production model (Fox 1970, 1975).

One very large problem faced by managers when aiming to assess the yield from this fishery is the fact that data from the recreational fishing sector, because of its very different nature, cannot presently be included within the yield model. This serves to complicate the job of fisheries management.

The Commercial Fishery

Management of barramundi stocks in the Northern Territory to date has been confined primarily to the commercial fishery. Active management of the commercial fishery commenced in 1962 although previous to this preliminary measures were introduced to licence fishermen and regulate for the submission of catch returns.

Management measures adopted since the early 1960s have been used to protect the stocks of barramundi and control effort in the fishery. The aims of management have been to maximise economic benefits from the fishery whilst maintaining viable population levels of this species throughout its habitat in the Northern Territory.

Initially, management of barramundi was undertaken primarily in response to biological advice on the state of the resource (i.e. estimated available yield and optimum effort capacity). More recently economic advice has also been considered in conjunction with biological factors when assessing and advising on management plans to meet the objectives listed above.

A number of management measures have been applied to this fishery over the last 25 years. Management plans are continuously monitored and revised and additional measures introduced as part of the management plan as required. The measures employed to date include: (i) limits on mesh size (180 mm) and legal length of fish to be harvested (58 cm) to protect sub-adult stocks; (ii) limited licence entry to control commercial fishing effort; (iii) area closures to limit access to sub-adult barramundi stocks in the freshwater habitat; (iv) gear restrictions (limiting the length of net to be used) to contain effort; (v) closed season (1 October to 31 January) — commercial harvesting ceases during spawning season; (vi) non-transferability of licences to control effort; and (vii) introduction of a buy-back scheme to reduce commercial effort by removing excess licences and nets permanently from the fishery.

Management measures were first introduced to protect sub-adult fish in the freshwater habitat. Measures included closure of freshwaters, introduction of a minimum mesh size for gillnets and minimum legal length of fish to be harvested.

In response to the results obtained from continuing biological research, further management measures were introduced to control effort within the fishery to protect the spawning stocks and promote the economic efficiency of operators.

An economic review of the fishery conducted in 1974–75 by Copes (1976) resulted in licence limitations being introduced. A biological review was conducted in 1978, involving assessment of all the biological research data available to date from various studies conducted throughout Northern Australia and New Guinea during this period (Garrett and Russell 1982; Davis 1981; Grey and Griffin 1979; Moore 1979, 1980 and 1982; Reynolds 1978; Reynolds and Moore 1973). This data, plus information obtained from surplus production modelling of the fishery based on catch data, indicated that effort was too high and catches were falling. At this time a closed season was introduced to protect spawning stock.

Non-transferability of licences was introduced in 1980 to ensure that a continuing blow-out in effort did not occur. Net lengths to be used by fishermen were restricted over a number of years so that now the maximum available to each operator is 1000 m. Licence fees were increased quite markedly to assist with removal of latent effort from the fishery and a buy-back scheme was introduced as part of the management plan in 1984 to actively remove excess net and operators from the fishery.

During 1985 a Barramundi Task Force was established to review the management measures applied to this fishery. The levels of exploitation of the resource by the different user groups (primarily commercial and recreational fishermen) and the practices for controlling barramundi exploitation were to be reassessed. As well, an evaluation was required of all available research material to determine the direction of future management strategies for this fishery.

Various management recommendations were made by the Task Force to the NT Government. Certain of those recommendations were adopted as part of the 1986-87 Barramundi Management Plan. They include:

(i) continuation of the current management measures, (ii) modification of the buy-back scheme so that prices offered as an incentive for buy-back were more in tune with the actual economic value of each fish operation, (iii) re-introduction of licence transferability once effort was reduced to 45,000 HMND (equivalent to 35 000 m of net), this target set as a result of reviewed etimates obtained from yield modelling, (iv) 50% funding of the buy-back scheme by industry (user-pays principle being adopted), (v) specific closures for the Mary River to commercial fishing at the mouth at the end of 1987, this management strategy being accompanied by an intensive research program to monitor both commercial and amateur fishing in this system, (vi) continued research funding to maintain appraisal and monitoring programs in specific river systems, (vii) assessment of the extent of recreational fishing pressure on the barramundi resource, especially in areas of high commercial and recreational usage, i.e. Mary River.

As a result of the management measures discussed above the number of operators in the fishery has been reduced from 113 in 1979 to 40 in 1986. Total net length licensed in the commercial fishery has also fallen from 169 500 m in 1979 to 35 000 m in 1986. Total effort has been considerably reduced from a peak of 100 700 HMNDs in 1979 to 65 700 HMND in 1985. Table 2 provides the data available on catch, effort, CPUE and operator numbers in the fishery from 1972 to 1985.

Recreational Management

Little consideration was given to the need for management of the recreational portion of the fishery until recent years.

Figures prepared by Griffin (1982) indicate that recreational fishing pressure on the barramundi resource in 1978–79 was limited in its extent and therefore not a matter for great concern at that time. Nevertheless some management measures were introduced in 1979 to control recreational fishing pressure including: (i) a bag limit of 5 fish per day per angler or a total of 10 per trip per angler; and (ii) as a one-off management measure the amateur fishery was closed during the 1978–79 wet season in conjunction with the commercial closure.

While no great concern was felt for the level of effort expended in the recreational fishery and its impact on the resource, plans were made to monitor the extent of recreational pressure from 1979 onwards.

Roadside surveys conducted in 1979 and again in 1984, provided some data on the extent of recreational fishing activities. Analysis of the results from these surveys suggested that recreational fishing pressure was confined primarily to the Mary, Alligator and Daly River systems (Griffin 1982; Griffin and White 1985). Preliminary estimates from data obtained during these surveys suggested that catch by recreational fishermen was approximately 20% of the volume of catch taken by commercial fishermen from the surveyed river systems.

More recently, extensive political lobbying by recreational fishermen has been carried out in an effort to reduce the number of commercial fishermen in this fishery so that a greater proportion of the resource is available to recreational fishermen. This lobbying resulted in a Government request for a more detailed analysis of the recreational barramundi fishery. Specific recreational research programs were implemented as part of the Barramundi Task Force recommendations. These are described as part of the Task Force recommendations listed earlier. Results of these programs are not yet available.

The Artisanal Fishery

Any management measures applied to this portion of the fishery have occurred as a by-product of commercial fishery management strategies rather than as a deliberate attempt to specifically manage this group.

Initial management measures to impinge on traditional barramundi fishermen were the issuing of commercial licences to a number of communities in 1980 to allow them to sell barramundi taken by the community as a commercial product. These licences were held until 1984 and were subjected to the same licencing, management and enforcement measures applying to all other commercial licences at that time (see earlier).

Because of frequent administrative and enforcement difficulties associated with the control of these 'commercial' aboriginal licences, combined with the fact that aboriginal people were only rarely using their gillnets (and then primarily to target on species other than barramundi), all aboriginal commercial licences were bought back as part of the management buy-back scheme in 1984.

Management measures were then introduced to allow for the establishment of an artisanal barramundi fishery, where unrestricted capture of fish by handline, spear, beach seine nets or harvesting by monofilament gillnet (up to 200 m) was allowed. Under the conditions of a D Class licence, the licenced community member(s) may capture barramundi to sell within their community only.

Because these users have such a small impact on the fishery, introduction of further management measures beyond those described above are not envisaged.

Future Management

While management controls applied to the harvesting of barramundi to date have been reasonably successful, there are other management-related factors

which the Dept. of Ports and Fisheries believes still need to be addressed to maintain optimum use and long-term viability of the resource in the future. These include: (i) continued re-assessment and revision of existing management plan; (ii) resolution of resource use conflict between commercial, recreational and traditional fishermen; (iii) continued investigations into the department's methods of stock assessment to improve its yield modelling techniques and thereby improve estimates of optimal catch and effort on which management decisions will be based for the total fishery; (iv) continued research, including further investigations into the distribution of separate barramundi stocks around the coastline and the implications of this to management, especially in the light of results obtained from recent genetic research conducted by Shaklee and Salini (1985) suggesting that there are a number of distinct genetic stocks of barramundi occupying distinct geographical regions across Northern Australia; (v) a review of the legislation to improve the effectiveness of management and enforcement controls; (vi) improved consultation with the various groups which utilise the resource when preparing management plans; (vii) investigation of the feasibility of barramundi aquaculture and its impact on wildstock management, e.g. harvesting broodstock from the wild; and (viii) the impact of area closures, e.g. National Parks and Aboriginal land claims, including the effect of displacement of fishermen from fishing grounds they have harvested historically to areas where fishing pressure is already at its optimum; (ix) assessment of management tools such as property rights to determine their usefulness in assisting the long-term economic and biological viability of the fishery. These factors will be addressed in future barramundi management reviews.

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Barramundi *(Lates calcarifer)* Research in the Northern Territory, Australia

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THE purpose of this paper is to summarise and describe the kind of research which has been conducted on the biology of, and fisheries for, barramundi in the Northern Territory and to present some results of that research.

Barramundi research in the NT began in late 1972 with a short-lived tagging program on the Mary River.

The next relevant work was on the fishery rather than the fish and took the form of a management review (Grey and Griffin 1979). The stimulus for that review was a dramatic fall in catch per unit effort in the barramundi fishery by approximately 70% from 1975 to 1978.

From this review it was obvious that for management of the fishery to proceed rationally there were a great many questions to be answered. Since that time research has been conducted basically in two directions: study of the fishery and study of the fish; but of course the two directions often crossed over.

Fishery Studies

When the downward trend in CPUE in the commercial barramundi fishery was assessed in the 1979 review it was immediately obvious that much more detailed knowledge of how the fishery operated and what factors might have affected catches was necessary. It was also obvious that the magnitude and impact of the recreational fishery, although presumed to be considerable, was virtually unknown. To fill in these gaps intensive monitoring of both sectors was undertaken.

Commercial Fishery

Observers were placed on board commercial vessels on an opportunistic basis to record details of operations such as net lengths and mesh sizes, and to measure and inspect catches. Initially the Van Diemen Gulf area was monitored but in 1981 sampling effort was shifted to the Daly River which at that time was the second most important commercial fishing area. Although it proved extremely difficult to obtain sufficient numbers of fish for precise statistical analyses the information collected was to assist greatly in interpretation and assessment of trends in the fishery.

Recreational Fishery

During 1978 and 1979 a series of roadside surveys of recreational fishermen returning from fishing trips to the Van Diemen Gulf area was conducted (Griffin 1982).

Total annual angler catch for the survey area was estimated to be approximately 80 t, which is 23% of the total catch.

Since that series of surveys a number of repeat surveys on selected days have been conducted and a new series, to assess changes in the recreational fishery, was commenced in January 1986. No results are yet available.

In addition to the roadside survey series, on-the-spot interviews with anglers on the water are being conducted at popular locations. These interviews will assist in verification of the data from the roadside survey series.

Additional information on the recreational barramundi fishery will be available later this year when a general survey of recreational fishing in the Northern Territory is completed. This survey, conducted by consultants, is investigating all aspects of recreational fishing in the Northern Territory.

Fishery Modelling

The status of the commercial fishery has been assessed using the Schaefer type surplus production model (Grey and Griffin 1979; Rohan et al. 1981). Unfortunately this technique has a number of inadequacies in this situation, but in the absence of sufficient data for any other kind of analysis, has proved to be useful in providing guidelines for assessment and management of the fishery. Later analyses have improved upon this technique using the methods of Fox (1975) and by assessing the fishery as a number of units rather than as a single stock (Grey and Griffin, unpublished data). Modelling and management are the subjects of another paper for this workshop (Lea et al. These Proceedings).

While the fishery was being managed on the basis of surplus production models, field sampling of

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barramundi populations was carried out to provide estimates of population modelling parameters such as growth, mortality and mesh selectivity. Because of complications of both biology and fishery practice (including mesh selection and seasonal changes in distribution of both fish and fishing effort) estimation of useful mortality parameters has not been possible. Growth data has not yet been fully analysed but does not appear to differ substantially from previous estimates from NT waters (Davis and Kirkwood 1984).

Mesh selectivity has been assessed from trials using 12.7, 15.2, 17.8 and 20.3 cm nets. It has been found that selection in barramundi does not follow the traditionally assumed normal pattern thus precluding any possible combination of capture probability and gillnet catch data to provide estimates of mortality via catch curve methods. New methods of selectivity estimation (Kirkwood and Walker 1986 in press) may provide for a more realistic analysis of this kind of data.

Biological Studies

The current management scheme for the barramundi in the NT includes a number of measures which are at least partially founded on biological knowledge of the species or general biological principles. These include: minimum legal size of 58 cm TL; closed season from 1 October to 31 January to protect spawning fish; river closures — commercial fishing is only allowed in lower estuarine areas. These three regulations apply only to commercial fishing. The recreational fishery is regulated only by a bag limit of 5 fish/day with a maximum of 10 fish/person.

In addition to these factors, it became apparent in studying the trends in the commercial fishery that there is probably considerable variability in both catchability and abundance of barramundi associated with changes in the pattern and intensity of wet-season rainfall. With all of these factors in mind research studies since 1980 have examined: timing of spawning and factors affecting it; seasonal movements and distribution of barramundi; levels of recruitment of 0+ fish and factors influencing it.

Spawning and the Closed Season

The closed season in its original form covered the period from 1 November to 31 January. It was first imposed in 1977 at the instigation of the NT Commercial Fishermen's Association in response to members' fears that capture of ripe females during the spawning season was a contributing factor in the decline of barramundi stocks. In 1979 the closed season was extended to commence on 1 October as industry reported that significant numbers of ripe females were being captured in October.

Because the closed season was in force when research began, collection of data on gonad maturity, etc. was logistically very difficult. Sampling was undertaken at the Daly River, southwest of Darwin in October, November and December of 1980 and 1981. Gillnets of 12.7 to 20.3 cm stretched mesh were set in the river mouth in a manner similar to commercial operations. Fish larger than 90 cm were killed for gonad examination while those under 90 cm were tagged and released if in suitable condition. Figure 1 shows gonadosomatic index (log gonad wt/log length) for female fish caught during the closed season sampling (Oct.–Dec.) and during commercial fishery monitoring (Feb.–Sept.). Although the numbers are very small (a problem also reported by Davis 1985) it can be seen that this index of maturity peaks in October and declines thereafter. Many of the females observed in November and December were possibly partially spent as the ovaries had a somewhat flabby appearance but were not spent, having large numbers of mature ova visible. The possibility of barramundi being partial spawners has been suggested by Davis (1982) and Moore (1979) but has not yet been proven. Plankton samples taken during these closed season sampling periods were inconclusive and failed to find any barramundi larvae or eggs.

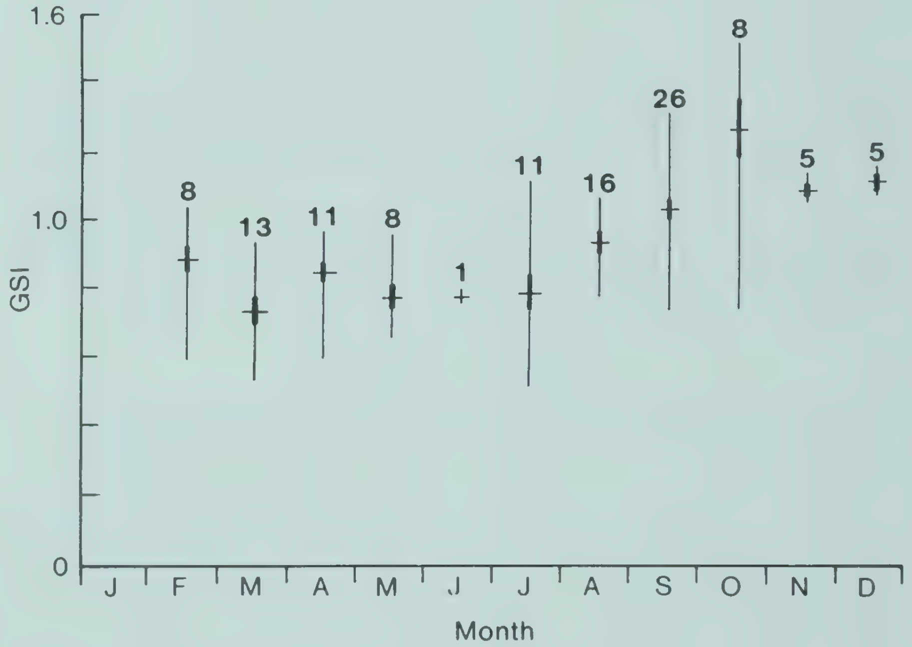

Fig. 1. Gonadosomatic index for female *L. calcarifer*.

Sampling of postlarvae in coastal swamps including Leanyer Swamp near Darwin (also sampled by Davis 1985) has revealed a monthly, tidal-based cycle of abundance in supralittoral pools (Griffin 1985). Postlarvae collected from Leanyer Swamp in early September 1984 ranged from 10 to 14 mm TL, indicating that spawning had occurred in August.

These results are similar to those reported by Davis (1985), and Russell and Garrett (1983). All of these studies highlight the importance of the supralittoral/coastal swamp habitat and the importance of early wet-season rainfall as determinants of barramundi recruitment.

Due to logistical problems, sampling of postlarvae from swamps at the Daly River mouth has not been as

regular as at Leanyer Swamp but a similar pattern of postlarval behaviour has been observed.

Distribution of postlarvae in tidal pools has been found to be extremely patchy. On a number of occasions large numbers were found in one pool while an adjacent pool, which was apparently identical, contained none. A possible explanation for this patchiness is that barramundi of this size travel in groups and as the tide recedes across supralittoral flats, pools remaining may or may not receive a school of postlarvae on a purely random basis.

Seasonal Movements

For a closed season of the kind in operation in the NT to be effective it must prevent the capture of ripe females at a time when their vulnerability to the fishery would have been substantially increased. In the barramundi fishery, as it operates in the NT, this could occur if mature fish moved from upstream tidal areas down to the mouth of the river where commercial fishing occurs. Alternatively, of course, fish could become more vulnerable to capture by moving from deep offshore waters to inshore areas where fishing occurs, but there is no evidence that a movement of this kind occurs.

There is, however, considerable evidence that a downstream movement of mature fish occurs on an annual basis with fish moving from upper tidal water into the fishing area at the end of the dry season. Such movement has been reported by Dunstan (1959, 1962) and Moore and Reynolds (1982).

The circumstances of the commercial fishery being only at the mouth of the river and capture for tagging purposes being easiest in upstream waters leads to a unidirectional 'flow' of tags which is difficult to interpret positively as a seasonal movement.

Griffin (in prep.) reported the results of studies of movements at Daly River which provided evidence that a downstream seasonal movement does occur on an annual basis.

A total of 1678 barramundi were tagged in July and August 1983 at three locations on the mid-tidal section of the Daly River, at 45 km, 51 km and 60 km upstream; 151 fish were recaptured. Of the recaptured fish tagged at 45 km, only 8.2% had moved upstream, compared to 50.8% from the 60-km site which had moved downstream. At the 51-km site only small numbers were tagged and recaptured (total of 13) but none was taken upstream. A total of 22 fish were recaptured three times. In nine of those, movement was progressively downstream, terminating with capture in the commercial fishery within 2 months.

The percentage of fish from that experiment recaptured by commercial fishermen in successive 15-day periods following tagging were: from 16 July: 1.0, 1.6, 2.7, 3.5, 4.0. The corresponding mean water temperatures at Daly River during the same periods were: 21.8, 22.2, 26.6, 29.3, 28.8°C. These data suggest that the probability of capture of the tagged fish increased as they moved downstream into the commercial fishery. A possible stimulus for this movement could be the rise in water temperature which occurs over the same priod.

Additional indications of downstream movement can be found in the pattern of commercial recaptures from Daly River on a monthly basis. Given that almost all releases of tagged barramundi have been made in upstream waters, commercial recaptures are generally a result of downstream movement. The monthly distribution of commercial tag recaptures is compared with the distribution of catch by month at Daly River (Table 1). The pattern of recaptures is significantly different to that which would be expected from the catch distribution ($\chi^2 = 25.71$; $p<0.05$). The apparently higher number of recaptures in August, September, and February is interpreted as being the result of movement of fish into the commercial sector.

Table 1. Proportion of commercial tag returns by month, Daly River, 1981–84.

Month	% Catch	Tag returns (%)
February	7.8	7 (13.2)
March	11.5	6 (11.3)
April	16.0	3 (5.7)
May	20.6	6 (11.3)
June	12.8	2 (3.8)
July	8.8	5 (9.4)
August	9.8	8 (15.1)
September	12.7	16 (30.2)

The significance of these results is that the closed season does have the effect of reducing catches of mature fish made more vulnerable by migrating into the commercial fishing zone.

Research sampling in areas upstream of the commercial zone of the Daly River (30–60 km) has resulted in much higher catch rates (CPUE (kg/hmd) at 60 km, 98; 45 km, 273; 8 km, 9.2) suggesting either greater abundance of fish in that area or increased catchability. This fact justifies the closure of the upper tidal areas to commercial fishing as a conservation measure in addition to its incidental function of keeping recreational and commercial sectors separate to a large degree. While catchability is probably somewhat higher within the confines of the river at the upstream locations these very large differences in CPUE strongly suggest much higher abundance at the upstream locations.

Seasonal Variability of Catch

A dominating feature of the ecology of northern

Australia is the extremes of climatic conditions associated with the typical 'dry' winter, 'wet' summer pattern. The 'dry' component of the climate is reasonably stable but the 'wet' is quite variable in both the total amount and pattern of rainfall.

Recent studies (Davis 1985; Russell and Garrett 1983; Griffin 1985) have suggested that early wet season rainfall (i.e. October–February) could have a significant effect on survival of barramundi in the coastal swamp environment during their critical early months.

Rainfall during the early wet season (before the monsoon period), particularly in October and November is spasmodic and scattered and in years where such rainfall is insufficient to replenish supralittoral swamps between spring tides, survival of postlarval and juvenile barramundi could be expected to be reduced. Higher levels of rain during this initial period could greatly enhance survival.

Monitoring of abundance of 0+ fish has been undertaken at Bamboo Creek on the Daly River since 1981. Large numbers of juvenile barramundi are concentrated at a culvert as floods subside in the late wet season period (March–April). They are prevented from moving further upstream by a flow of approximately 3 m/sec or more in the culvert pipes and are easily captured on the lower side by cast netting or angling. Griffin (1985) reported the result of 3 years of sampling at this location. A further 2 years of sampling (1985, 10 fish/day with pre-March rain of 950 mm– (–6%); for 1986, 20 fish/day and 990 mm (+2.4%)) has showed essentially the same relationship between juvenile abundance and early wet season rainfall (r = 0.81). Because other activities were accorded a higher priority, sampling in 1986 was disrupted and the optimal sampling time may have been missed.

In quantitative terms this sampling is perhaps less than optimal as the effectiveness of cast netting is quite variable. However, the overall observed trend probably reflects a real variation in abundance. Sampling at the Bamboo Creek site and others is continuing and methods of improving accuracy and repeatability of sampling are being investigated.

On this assumption the relationship between barramundi abundance (as reflected in commercial catch per unit effort) and early wet season rainfall in the Northern Territory in previous years was examined. As the majority of the commercial catch in the NT is composed of 3- and 4-year-old fish, lags of 3 and 4 years were tested. No significant relationship was found between CPUE and rainfall either 3 or 4 years before.

A direct relationship was found, however, between commercial CPUE and rainfall in the preceding wet-season rainfall:

$$\text{CPUE} = 0.023168 \text{ rain (mm)} - 19.666 : r = 0.69$$

Dunstan (1959) found a significant correlation between catch and river discharge in the Fitzroy and Burdekin rivers in Queensland. This relationship can perhaps be explained by postulating a general movement of fish downstream when salinity is lowered in the commercial zone by monsoon floods and movement upstream out of the commercial zone as floods recede. This theory depends upon barramundi preferring the brackishwater habitat.

The previously mentioned apparent higher abundance of fish in the mid-tidal reaches of the Daly River during the dry season lends some credence to this theory. Thus it is possible that heavy and prolonged wet-season rain acts to increase catch and CPUE in the commercial fishery in the NT by extending the period of maximum availability in the commercial zone. This aspect is being further investigated.

Recent research has endeavoured to concentrate on aspects of seasonal variations in catchability and year-class strength with a view to improving the reliability of population assessments and yield estimation.

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Analysis of Fisheries Logbook Information from the Gulf of Carpentaria, Australia

R.H. Quinn*

BARRAMUNDI is fished extensively in Queensland waters by both commercial net fishermen and anglers who consider 'barra' a highly-prized sports fish. The commercial fishery for barramundi is centred on the Gulf of Carpentaria, although it forms a valuable component of the east coast mixed fishery.

In December 1980 management measures were introduced to the Queensland gillnet fishery. The fishery was divided into two mutually exclusive areas: the Gulf of Carpentaria and the east coast of Queensland. All master fishermen involved in the fishery had to have their licences endorsed to operate in only one of these regions. Entry into the fishery was on the basis of the individual fisherman's historical and financial involvement in the fishery, and his ability to produce a high quality product.

Within the Gulf of Carpentaria gillnet fishery, endorsement is limited, strictly controlled and reviewed annually. Each endorsement holder is required to have a fulltime commitment to the Gulf gillnet fishery for a minimum of 20 weeks in any calendar year. In this context fulltime gillnetting encompasses net setting, gear and boat maintenance, marketing and other ancillary operations associated with this fishery. Also endorsement holders are required to meet a minimum catch quota of A$10 000 a year derived solely from the gillnet fishery.

A production return is required from all endorsed licence holders to document time commitment to the fishery and landed catch. Logbooks containing 12 returns are issued annually and the completed returns are submitted on a monthly or per-trip basis. Data required on the return includes the region along the coast being fished, the site at which the net was set (foreshore or river), the average length of net set, the mesh sizes and the number of days set. On any one return, several different fishing localities can be recorded.

This paper presents the results of analyses of the logbook data from 1981 to 1985. The logbook program has only been operating since 1981 and therefore interpretation of these results is limited. Barramundi reach commercial size when they are between 3 and 5 years old. Therefore, in excess of 5 years of data collection is needed before the impact of the management program can be evaluated.

Results and Discussion

In 1980, 306 master fishermen applied to enter the Gulf barramundi fishery. Only 211 were considered to be eligible because of entry requirements. Of those eligible, 191 sought endorsement for 1981. The number of master fishermen maintaining endorsement has declined each year; only 113 endorsements were issued in 1986. Failure to meet the endorsement requirements of the fishery was the major reason for this decline.

Although the number of the fishermen endorsed has been reduced to about 40% of the initial number, the amount of effort measured as either number of days that nets were in the water (net days) or as 100 metre net days (Table 1) has reduced only slightly. This clearly demonstrates the amount of latent fishing effort which was held by those masters who failed to obtain endorsement over the 5-year period.

Fishermen in the Gulf of Carpentaria either fish with short nets (maximum length 360 m) in the tidal reaches of rivers, or longer nets (maximum length 600 m) on the foreshore. The proportion of effort which occurred in the rivers, as opposed to the foreshore, was relatively stable. The river nets have a higher catch per 100 m of nets than foreshore sets (Table 1) although the catch rates are similar on a day basis (Quinn 1984). Reasons for the lower catch rate on foreshores have been proposed by Grey (1985) who states that the fishing power is lower because the net has less depth (e.g. 16 meshes compared to 33 or 50 for river sets), although this may be compensated for by an increase in fishing time due to reduced tidal currents.

The logbook results show that the foreshore catches are highest in February and March (Fig. 1). The catch rate declines over the winter months, then increases until the closed season is imposed from November. The river catch rate does not show the fall during winter, but gradually declines until the closed season

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Table 1. Summary of the logbook information for the total fishery in the Gulf of Carpentaria. Catch per unit effort based on whole fish per 100 m net days.

	1981	1982	1983	1984	1985
Catch (kg fillets)					
Barramundi	372261	360546	273637	344748	315831
King Salmon	232650	190271	182435	200418	222424
Total*	758793	744523	611453	700169	575166
Effort					
No. of licences	160	140	130	130	113
No. of net days	22922	23011	22505	20499	21065
100 m net days	101434	93116	98750	88670	96792
% effort in River (100 m net days)	39	43	35	46	45
CPUE					
Barramundi					
River	11.33	10.67	8.62	12.32	10.52
Foreshore	5.90	6.82	5.06	6.80	4.59
Total	8.07	8.51	6.09	8.56	7.17

* Total includes other species not listed here.

(Fig. 1). The periods of high catch rates correspond to periods adjacent to spawning period of barramundi when they move to the mouth of rivers and correspond to the start and end of the wet season. Dunstan (1959) reported a positive correlation between monthly catches for rivers on the east coast of Queensland and river flow. This pattern of monthly catch per unit effort for foreshores is similar to that observed for the Cambridge Gulf Fishery (Morrissy 1985).

The catch of barramundi from the Gulf of Carpentaria, although showing year to year variations, has remained relatively constant. The catch of king salmon (*Polydactylus sheridani*) and the total catch has also remained relatively constant over the 5-year period. This was reflected in stable catch per unit effort for the river and the foreshore and for the total fishery (Table 1).

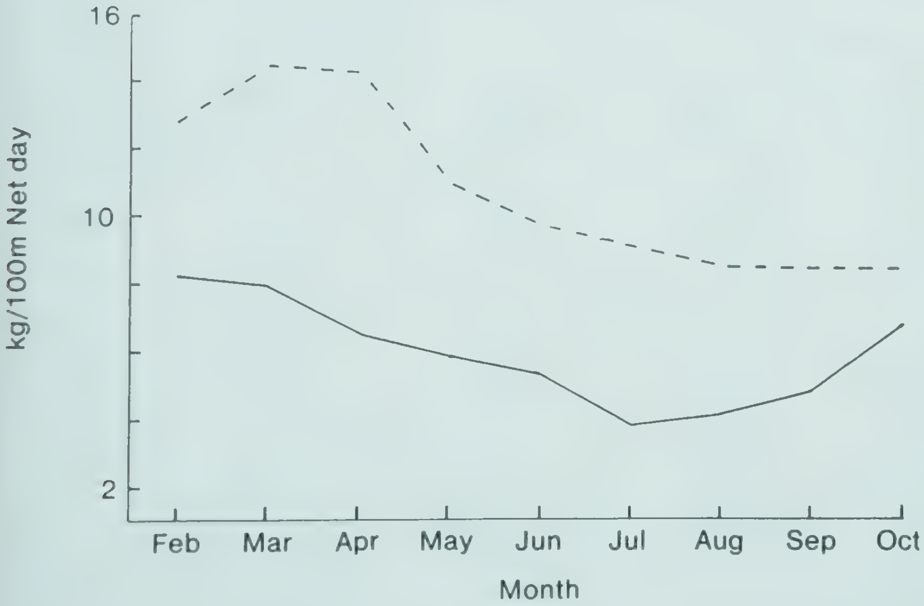

Fig. 1. Average monthly catch of barramundi for the years 1981–85 for River (..........) and foreshore (______) expressed as kg/100 m net days.

The results so far published represent a stable fishery with catch, effort, and the distribution of effort (foreshore or river) being constant.

However recent work by Shaklee and Salini (1985) has shown that there are a number of genetically distinct stocks of barramundi in Northern Australia. This result has been supported by tagging studies which has shown little movement of tagged barramundi between river systems. For example from over 3000 tagged barramundi released in the Daly River in the Northern Territory, no tags have been returned from adjacent river systems (Grey 1985). The tagging studies showed that coastal movements of less than 50 km are typical of barramundi in Australia with movements rarely exceeding 100 km (Shaklee and Salini 1985).

The Gulf of Carpentaria cannot be considered as a single stock. From a fisheries viewpoint, the data should be divided into a unit stock basis and examined at this level. The Gulf of Carpentaria was divided into four areas when the logbook program was first established in 1981. The four areas are: Area A extends south to just below Weipa; Area B extends to midway between Weipa and Karumba; Area C extends beyond Karumba to north of Burketown; and Area D extends west of Burketown to the border. The fishery has undergone changes when the catch and effort expressed as net days and distribution of effort (Table 2) are considered on an area basis.

Although the lengths of coastline in each of the four areas are approximately equal, the amount of effort conducted in each area is far from equal. Approximately 60% of the effort was restricted to Area C (Table 2) while more than 20% was in Area B and less than 10% of total effort was in Areas A and D.

Table 2. Summary of catch of barramundi (fillets kg), effort (net days) and the percentage of effort used in the river for the four areas in the Gulf of Carpentaria.

	1981	1982	1983	1984	1985
Area A					
Barramundi (kg)	5438	11444	12156	10030	6514
Effort	645	663	890	911	478
% effort in River	66	98	86	75	72
Area B					
Barramundi (kg)	109259	124254	68595	89547	119046
Effort	4913	6342	5498	4096	4821
% effort in River	49	49	26	51	60
Area C					
Barramundi (kg)	217012	195051	156490	185618	158014
Effort	15695	14487	13063	12559	12747
% effort in River	35	40	35	48	38
Area D					
Barramundi (kg)	40552	29797	36396	59553	32257
Effort	1669	1519	3054	2933	3019
% effort in River	17	24	56	65	63

Fishermen in the Gulf barramundi fishery are based at Weipa, Karumba and Burketown. Approximately 75% of fishermen are based in Karumba which is within Area C. From here, fishermen travel and net the adjacent areas of B and D as well as Area C. Burketown which is the home port for approximately 10% of the fishermen is in Area D near its boundary with Area C and fishermen fish both areas. The remainder of the fishermen are based at Weipa between Areas A and B and fish these areas. The fishermen in the Gulf have therefore established home ports close to their fishing grounds. However, the localities of these ports may restrict effort in some of the more remote regions. Area B generally has a higher catch per unit effort to the other areas (Table 3). Effort may be limited in Area B due to the distances needed to travel to this area, and the need for a suitable vessel (size of vessel and freezer capacity) to work this remote area. There is also a cost in terms of travelling time which would reduce the effective catch rate per trip.

The Gulf of Carpentaria does not have a uniform coastline. For example, Area A does not have wide foreshores or mudflats, and only has a few river systems suitable for netting of barramundi. This area has low effort centred mainly on the rivers (Table 2). This contrasts with Area D where effort was based in 1981 and 1982 on the foreshores and mudflats. In 1983, effort doubled, the increase representing a greater utilisation of the river systems. Areas B and C have a large number of rivers and wide foreshore areas suitable for netting. Foreshore and river sites in these areas are fished approximately equally (Table 2).

The majority of the fish caught in the Gulf of Carpentaria are filleted to save on freezer space. Barramundi recorded as fillets have been converted to whole fish by assuming a recovery rate of 45% (Garrett, pers. comm.) for the analysis of catch per unit effort expressed in Tables 1 and 3. This allows comparison with catch rate from the Northern Territory and Western Australian fisheries. The catch rate for the Gulf of Carpentaria combined has varied little on a

Table 3. Summary of catch per unit effort (100 m net day) for the four areas in the Gulf of Carpentaria.

		1981	1982	1983	1984	1985
A	River	6.38	10.56	6.60	3.48	5.06
	Foreshore	4.14	9.94	7.90	10.16	7.85
	Total	5.63	10.45	6.93	5.10	7.13
B	River	15.27	12.83	6.51	15.40	14.28
	Foreshore	8.78	10.12	5.28	11.30	8.60
	Total	11.33	11.40	6.23	12.01	11.73
C	River	10.56	9.81	9.88	12.28	9.66
	Foreshore	4.51	5.28	4.77	5.50	3.78
	Total	7.02	7.22	6.05	7.81	6.09
D	River	9.88	9.31	8.10	11.75	6.64
	Foreshore	11.66	9.86	6.31	10.96	3.10
	Total	11.31	9.72	6.78	11.29	4.36

yearly basis from 6kg/100m net day to 8.5 kg/100m net day (Table 1). However on an area basis there have been large variations between areas and within areas over the 5-year period (Table 3).

The fishery in Papua New Guinea based on local fishermen showed a decline from 20–43 kg/100 m net day in 1965 to 15–20 kg/100 m net day in 1979, although freezer boat operators have obtained catch rates as high as 100 kg/100 m net day using monofilament nets. This fishery was regarded as being underutilised (Hill and Grey 1979).

Catch per unit effort in the Northern Territory has declined more dramatically from a range of 20.5 to 28.8 kg/100 m net day in the early seventies to 7.4 to 8.6 kg/100m net day in the late 1970s due to a large increase in fishing effort (Grey and Griffin 1979; Rohan et al. 1981; Grey 1985). The latter catch rate is similar to that of the Queensland Gulf of Carpentaria fishery. Unfortunately there are no figures from the commercial fishery for the 1970s. From anecdotal information on this fishery, the catch rates were higher than present levels in the late 1960s and early 1970s.

The catch per unit effort of the Northern Territory includes both river and foreshore catches. Grey (1985) discussed changes in the fishery which would result in changes in catch per unit effort without reflecting changes in abundance of barramundi. The type of nets has changed from multifilament cord nets being replaced almost entirely by monofilament nets. The fishery in the Northern Territory is incorporating a higher proportion of mudflat (foreshore) fishing in recent years. This is evidenced by the higher catch of king salmon in 1976 (375 t) which was more than double the 1975 figure (154 t). The change to foreshore netting would reduce catch per unit effort of the whole fishery as foreshore sets have a lower catch rate than river sets.

Queensland logbooks show that there has been no major change in fishing strategies over the 5-year period (Table 1) although in 1983 more time was spent fishing on the foreshore than for other years. This year had the lowest catch rate and catch of barramundi, and although more time was spent fishing on the foreshore, the catch of king salmon was also lower than average.

Assessment of yields of the Gulf of Carpentaria fishery based on the surplus production model was not undertaken. The effort, catch per unit effort and catch have been relatively constant in the total fishery and for each of the areas since the introduction of the logbook program in 1981. As both Schaefer and Fox models require regressions between these variables, reliable estimates of parameters can only occur when there is contrast in the data. It is therefore not possible to predict where on the yield curve the Queensland fishery is. The fishery could have excess effort but a constant low catch rate or be underutilised with a similar result. This fact shows the importance of obtaining logbook information from the commencement of a fishery when the fishing effort is low to provide contrast in the data.

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Barramundi (*Lates calcarifer*) Fishery Management in Queensland, Australia

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Management arrangements for conservation of wild stocks of barramundi in Queensland are entering a fourth phase of their development. This phase represents an important step in a continuum that commenced more than a decade ago when claims of declining catches drew attention to this important commercial, recreational and sports fishery.

Arrangements Prior to 1976

Legislative controls on fisheries have existed in Queenland since the turn of the century. However, prior to 1976, those controls contained no specific focus on barramundi as a species warranting special consideration. General provisions applied to licenced set net fishing operations whilst a minimum size limit was also in force. However increasing interest was being shown in the fishery from both commercial and recreational sources. Entry to the commercial ranks was relatively free from impediments and persons who could marshall sufficient resources to do so took advantage of that opportunity.

Low barriers to entry to the commercial fishery in 1975 attracted new operators, many of whom had little or no training other than past recreational experiences on which to base their operations. As a result, more than 30% of licence holders did not return to the industry the next year.

New Management Arrangements

In response to public concern about the status of the barramundi industry, interim measures were introduced into the fishery in 1976 to place a brake on fishing pressures in the more important river systems, to protect juvenile and maturing adult fish during their vulnerable stages, thus providing a reservoir of fish for seasonal and migratory replenishment of fish stocks. The strategy chosen to achieve that objective was the closure to net fishing of 22 river systems, 6 on the East Coast and a further 16 flowing into the Gulf of Carpentaria.

Establishing the Need for Management

The research program initiated in 1978 involved joint participation of Queensland and Northern Territory governments' fisheries agencies together with CSIRO. These three agencies, together with other international representatives had conducted an appraisal of data generated from their research activities from which was developed a discussion paper on the need for management of the fishery in Queensland, and the strategies that might be appropriate for that purpose.

Researchers established the desirability of a closed season concept during annual spawning periods but not its timing nor scope. They also established the need to limit the growth of recreational and commercial fishing effort, the limited migratory characteristics of the species (in Queensland) and the need for protection of identified juvenile nursery areas. The paper drew attention to the uncertainty which still existed about the behavioural characteristics of barramundi.

The discussion paper was circulated to individuals and groups that had previously shown interest in the matter. More importantly it established a process of open consultation on the matter which subsequently became an essential ingredient in the successful implementation and continuing review of the management scheme.

A package of management strategies was presented to industry and amateur bodies and subsequently introduced into fisheries law in the latter part of 1980.

New Management Strategies

The following is a summarised version of the management package introduced into fisheries legislation and administrative arrangements for conservation of wild stocks of barramundi in Queensland commencing in late 1980:

(i) the introduction of a Closed Season for the months of November, December and January during which the taking of barramundi would be prohibited;

(ii) the banning of all set netting operations in rivers and territorial waters of the Gulf of Carpentaria and of river set netting on the East Coast during that same period;

(iii) the introduction of two mutually exclusive limited licence regimes, one in the Gulf of Carpentaria with the other comprising river and foreshore areas of the

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East Coast of Queensland from Cape York to Baffle Creek (near Bundaberg);
(iv) a standardisation of minimum set mesh sizes to 150 mm (6") for set nets available for use north of Cape Flattery (i.e. Cape York and the Gulf of Carpentaria);
(v) the introduction of an amateur 'bag limit' enabling anglers to be in possession of a maximum of five fish (barramundi) at any one time;
(vi) the protection of known breeding grounds by extending habitat reserves and fish sanctuaries;
(vii) enhancement of enforcement capabilities consistent with the needs of the management plan;
(viii) provision for annual review of the overall management program.

The eight elements of this legislation continue to be the essence of the management scheme.

Present Concerns and Directions

The task now facing fisheries managers is to consolidate the achievements to date whilst minimising or removing any weaknesses that are inherent in any plan over time. The fundamental strength now evident is that the strategies taken in 1980 have been confirmed on biological grounds as being appropriate for the fishery.

Some weaknesses still exist:
(i) in view of the non-migratory characteristics of barramundi, habitat and nursery area protection mechanisms need to be spread widely throughout the fishery;
(ii) whilst commercial fishing effort is limited and documented, little is known of the recreational component particularly in the Gulf fishery;
(iii) little business flexibility exists for commercial operators under present arrangements, and
(iv) the level of knowledge and understanding of the program by the general community is considered to be low.

Each of these weaknesses comprise the purpose of the present phase of the management program and strategies to overcome them are addressed in the following paragraphs.

Difficulties were encountered in implementing habitat protection measures in the 1980 version of the program. These difficulties necessitated a rethinking of the approaches taken. The Queensland Government has established and is progressively implementing an estuarine inventory program which on completion will see extensive reservation of fisheries habitat and wetlands throughout the state appropriate for conservation of all fish species. This program is well underway with most of the east coast areas now protected. Reservation of similar areas adjacent to the Gulf of Carpentaria has now progressed to formal stages of consultation required by legislation, the areas of interest having been established and mapped. On completion of this process, habitat protection measures appropriate for conservation of this fishery will have been established.

In respect of the recreational fishery, it is not considered feasible, nor from a tourism point of view desirable, to reduce or even limit the number of anglers in the fishery. Many strategies are present to control and limit commercial effort and those strategies have been pursued successfully. The only mechanism realistically available to control growth of angling effort is a 'bag limit.' Such a mechanism is in place on the east coast limiting catches to five fish per person at any one time. In 1980, serious concerns were identified at the size of the recreational catch in the Gulf.

Coincidentally, commercial operators in the Gulf limited licence fishery have become increasingly concerned at a perceived serious upsurge of illegal netting by unlicenced people in remote areas of the fishery. Their concerns were expressed not only for stock conservation purposes but also due to the fact that they were being blamed for these activities.

To advance the level of knowledge of the recreational fishery in the Gulf area, a survey of participants was initiated during 1986. Responses from that survey, once collated, will enable the development of appropriate management measures for the recreational fishery in the Gulf of Carpentaria. Such measures will include provisions for overcoming the enforcement difficulties which retarded measures for the recreational fishery originally included in the program in 1980.

It is quite apparent that there is a need for greater public understanding of this management program and of its achievements to date. Throughout the program, pressures have been placed on fisheries managers to set aside areas of the fishery free from use by commercial operators. These pressures have been strongly resisted for two reasons: (i) closure of river and foreshore areas to commercial fishing (particularly if all self-interest groups' views were accommodated) would seriously concentrate commercial effort to the long-term detriment of the resource, and (ii) commercial operators to date have clearly borne the brunt of restrictions applied over the past 6 years to the fishery.

Summary

One feature of the success of this managed fishery to date in Queensland is the degree of consultation and cooperation which has been achieved by managers, researchers and users of the resource in seeking to achieve long-term solutions to conservation of this valuable species. It is imperative for continued success that the mutual trust evidenced by experiences to date remains an essential ingredient of the program.

It is believed that there no longer exists the need for rapid changes in direction for management of this

fishery. Change should now be introduced carefully and only after thorough consideration of the consequences of that change on barramundi stocks.

Continued research and monitoring of the fishery is strongly recommended to ensure that fisheries managers have the benefits of knowledge on which to base future strategies for conservation of this important resource, the barramundi.

Status of the Barramundi *(Lates calcarifer)* Fishery in Western Australia

N.M. Morrissy*

BARRAMUNDI stocks in the coastal tidal waters of the arid northwest region of Western Australia provide only a small commercial fishery, currently about 60 t annually. There are only a few small towns in this region and fishing is based mainly at Derby and Wyndham adjacent to the Kimberley area. Catch and effort statistics from compulsory monthly fishermen's returns are available on computer file (Australian Bureau of Statistics) from 1975–76 and have been summarised by Morrissy (1985).

Until recently management concern for this isolated fishery, by the Western Australian Department of Fisheries based in Perth in the southwest, has been of minor priority, e.g. for conflict between commercial and recreational fishermen on the Ord and Fitzroy rivers. However the development over the past 20 years of a major impoundment on the Ord River (Lake Argyle, 70 000 ha), and associated large-scale crop irrigation adjacent to Kununurra (south of Wyndham), has required attention on the question of fish passes, pesticide pollution and aquaculture proposals and potential (Morrissy 1969, 1983). Some experience has been gained over the past decade in aquarium rearing of barramundi to large sizes at the Western Australian Marine Research Laboratories near Perth (House 1979).

In May 1985, the first field program on barramundi in Western Australia was commenced by basing a technical officer at Wyndham. Experience was gained in the Cambridge Gulf area on commercial fishing methods and catches over 1 year as a prelude to the anticipated introduction of a closed season in line with Queensland and the Northern Territory. This small program has been extended until the end of 1986, subject to further review, with current emphasis on culture of barramundi in a research facility established at Wyndham port.

Relative to other fisheries the small Western Australian barramundi fishery is only locally important as a source of fresh, high-quality fish for northwest towns-people. The increasingly sparse coastal distribution of stocks southwards extends to Onslow, representing the southern limit of the species on the arid west coast of Australia. Most interest in the species in Western Australia centres on its tourist value for recreational fishing, and prospects for culture, particularly in the Ord River development area.

Distribution

The coastal distribution of commercial catches of barramundi (sea bass) is recorded in degree latitude and longtitude 'blocks' on Australian Bureau of Statistics returns (for species 552 — barramundi), and is somewhat blurred by inclusion of sand bass or reef barramundi, *Psammaperca waigiensis*. The very small catches of sand bass are taken by handlining rather than by the gill (set)-netting used predominantly for barramundi. Barramundi do not occur in the offshore blocks (islands) along the riverless 'Eighty Mile Beach' fronting the Great Sandy Desert, further south near Carnarvon (Gascoyne River and Shark Bay) or at the offshore Abrolhos Islands (as frequently quoted from Whitley 1959).

The southern limit to the distribution of all known records of barramundi on the west coast is the Ashburton River (estuary) near Onslow. This locality is considerably lower in latitude than the corresponding southern limit on the east coast of Australia, in the Mary River, where the limiting environmental component has been considered to be low temperature (Dunstan 1959). Except for the extreme northwest Kimberley coast and inland Mitchell Plateau there, the west coast and inland catchments are characterised by aridity, increasing southwards. Significant rainfalls occur infrequently on the Pilbara Coast, with the passage of cyclones, and tend to occur later in the summer season than the monsoonal rains farther north.

As well as setting the southern limit to the distribution of barramundi on the west coast, the degree of aridity northwards appears also to determine the small size of the Western Australian fishery by limiting the extent of freshwater habitat for juvenile production.

Extensive river flood-plains, characteristic of the Northern Territory and Queensland, which reliably

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provide supralittoral habitat for larval and early juveniles during the wet season and permanent lagoons during the dry season, do not occur in Western Australia. Inland habitat is confined to isolated pools along the (non-perennial) rivers during the dry season with irregular and ephemeral flood plain inundation during 'The Wet.' There are no prime barramundi rivers of the type described in Queensland by Dunstan (1959). Extensive upstream migrations of juveniles occur during the later part of the wet season in the major Ord (now dammed) and Fitzroy rivers of low gradient, bordering the Kimberley. However, such migration is curtailed in the higher gradient rivers draining the central Kimberley (e.g. from Mitchell Plateau). The depositional estuaries of the Ord (Cambridge Gulf) and Fitzroy (King Sound) rivers are characterised by extensive salinised mudflats flooded only ephemerally and very shallowly by spring tides. No rivers occur on the Broome Coast where small barramundi stocks reside in tidal creeks and freshwater runoff is diffuse. Pilbara 'desert' rivers, while containing isolated freshwater pools, are highly irregular in flow for inland migration.

Thus, the low and varying abundance and patchy distribution of barramundi in Western Australia has been usefully ascribed, for management purposes, to unfavourable juvenile habitat, e.g. by comparison to the habitat types categorised by Dunstan (1959) by association with levels of stock abundance. Survival of larval and early juveniles occurs in the Kimberley in tidal waters of normal sea salinity. But this 'base line' production of juveniles is considered to be insufficient alone to maintain mature stocks in the long term because of a low level of survival due to predation and competition in tidal waters. And the evident association between the coastal distribution of barramundi stocks and river systems is thought to be a reflection of the dependence of recruitment on the extent of juvenile nursery protection afforded by inland habitat.

Fishery

Consistent fishing along the northwest coast for barramundi over the 12 years to 1984–85 has occurred only in Cambridge Gulf, the King Sound/Fitzroy River area, and on the Broome Coast (Table 1). By comparison catches on the Kimberley and Pilbara coasts were sporadic and highly variable with erratic changes in catch rates indicating exploratory fishing on small but highly vulnerable, accumulated stocks, incapable of sustaining consistent fishing.

The total annual Western Australian catch was about 30 t until 1982–83 when it more than doubled. Most of this increase was due to an increase in catch in Cambridge Gulf where stocks have been most abundant. The increase in the number of fishing boats over the whole Western Australian fishery was not a significant factor, being largely applied to exploratory fishing elsewhere.

The increased catch in Cambridge Gulf was due to an increased catch rate in 1982–83 by two long-term resident boats, there being no increase in the small numbers of boats (5–6) there over the period. In 1982–83 the Cambridge Gulf catch was 28 t (CPUE, 46.1) but declined in 1983–84 (20 t, 31.3) and

Table 1. Western Australia barramundi catch statistics.

	1984–85		Mean over 10 years	
Localities, Rivers, Block No.	Annual catch (*kg*)	CPUE[a]	Annual catch (*kg*)	CPUE
Cambridge Gulf; Ord, King, Pentacost Durack and Forest R. (1428, 1528)	12614	16.8	13930 (10)[b]	33.0
Berkeley R. (1427)	—	—	1781 (1)	3.2
Drysdale, King Edwards R. (1326, 1426)	16855	5.8	5862 (6)	16.7
Lawley, Mitchell R. (1425)	1400	11.8	2747 (4)	12.7
Prince Regent R. (1525)	1026	6.7	2721 (5)	25.8
Aboriginal Reserve (1524)	2839	9.5	914 (6)	27.7
Isdell, Charnley R. (1624)	8042	19.6	2458 (8)	22.2
Outer King Sound: Robinson R. (1623)	4087	17.3	2744 (10)	21.5
Fitzroy, May, Meeda R. (1723)	5135	26.2	5941 (10)	21.5
Broome Coast (1722, 1822)	3212	5.5	2330 (10)	5.8
Eighty Mile Beach (1821, 1921, 1920)	—	—	—	—
De Grey, Yule R. (1919, 2018)	2756	3.6	3141 (5)	9.1
Harding, Sherlock R. (2017)	—	—	2019 (3)	43.4
Fortescue, Robe, Cane R. (2016, 2115)	1250	1.8	336 (5)	8.6
Ashburton R. (2114)	59	2.4	680 (4)	24.6

[a] Catch per day per 100 m net length.
[b] Number of years catches recorded.

1984–85 (13 t, 16.8). The total Western Australian catch was sustained at the 1982–83 level in these subsequent years by increased exploratory fishing by the Wyndham boats on the Kimberley coast.

Concern over this recent trend in the catch statistics for Cambridge Gulf has been increased by expressing fishing effort as '100 m net lengths × (net) shots' rather than as '100 m net lengths × days' (Rohan et al. 1981; Morrissy 1985). Recorded net shots per day averaged one prior to 1982–83 but since then has increased to 2–3/day.

Interpretation of the conventional catch rate (CPUE — catch per unit of effort)/fishing effort (E) relationship is further complicated by an apparent influence of wet season flooding (rainfall) on fishing effort and catch rate level within and between years. Monthly catches (<500 kg) over the fishing year show minimum levels during the mid wet season period December–February, a similar pattern to that found in the Northern Territory (Grey and Griffin 1979) but the opposite to that shown in the Queensland East Coast fishery (Dunstan 1959). Between years the relationship between annual catch rates and rainfall has been found to be positive in the Northern Territory (R. Griffin, pers. comm.). From this relationship it could be implied that increasing river flooding increases the movements of fish and, hence, their vulnerability to set nets. However, the year-to-year variation in Cambridge Gulf catch rates is difficult to interpret at present since low catch rates have been recorded in years (1978–79, 1981–82) of well-above-average rainfall (755 mm) at intermediate levels of fishing effort.

A limited amount of sampling of commercial catches from Cambridge Gulf was conducted in 1985–86 by our Technical Officer stationed in Wyndham. Ageing by scale analysis indicates a lower mean growth rate than that summarised as the general pattern for fish in the Northern Territory, Queensland, and Papua New Guinea from values given by Hill and Grey (1979), Reynolds and Moore (1982) and Davis and Kirkwood (1984). Some validation for possible extra-annual checks is being carried out by examining frequency modes of back-calculated lengths. Mean sizes of identifiable males and females in catches were 720 mm (5+ years) and 910 mm (9+).

The 1984–85 wet season in the Wyndham area was one of below-average rainfall (543 mm, long-term mean 775 mm) and drought conditions prevailed until January 1986 (328 mm, mean 161 mm). Gonad sampling and catches of 0+ group juveniles in 1986 showed that spawning of fish in tidal waters occurred in November and December 1985.

Culture

An onshore tank facility was established on the approaches to the Wyndham port jetty in 1985. Fish have been maintained in a single pass system, in 15 m^3 or 5 m^3 tanks, with pumping and settling systems designed for coastal waters characterised by extreme diurnal tides and high turbidity. Considerable experience was gained during late 1985 in the catching, transportation and husbandry of wild fish. Fish that recovered from gill net shock and injury survived through until April 1986 when all were lost due to heavy gill infestation with *Amyl oodinium* (identified by Dr R. Lester, Queensland, from slide preparations by Dr L. Evans, Western Australian Institute of Technology, Perth). Further infestations of fresh stocks have been avoided through formalin treatments, and fish are now subjected to routine quarantine and prophylactic treatment.

During the 1986 winter season tourist viewing of the facility was permitted on a trial basis. We hope to carry out observations and experimental work during the late 1986 natural spawning period, subject to a degree of uncertainty as to salinity conditions, based upon previous records. Despite the enormous diurnal tidal bore, the Wyndham area at the head of the channel entering Cambridge Gulf is subject to the influence of five rivers. Commitment of government funding on barramundi research at present extends to the end of 1986.

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Barramundi *(Lates calcarifer)* Management: Operational and Economic Conditions and Buy-Back

David Campbell*

THE Northern Territory inshore gillnet fishery is based on two species of fish: barramundi (*Lates calcarifer*) and threadfin salmon (*Polynemus sheridani*). While other species of fish are taken, these landings are minimal. To this stage, approximately three-quarters of the value of landings is from barramundi, with the remaining quarter from threadfin.

Up until after World War II, most barramundi were taken for local consumption by fish trap from Darwin Harbour. Ready access to army surplus four-wheel drive jeeps after the war saw operators moving to areas beyond Darwin Harbour and to the use of set gillnets. During this period there was greater use of ice for holding and transport of barramundi.

The next major technical change in the fishery came after the introduction of river closures in 1972. Land-based operators found themselves restricted in their ability to gain access to the fishing grounds, particularly during and following the monsoonal wet. As a consequence an increasing proportion of operators have moved to boats (Grey and Griffin 1979). The shift in the mode of operation has resulted in not only greater access to river mouths, but to foreshore mud flats. While this change in method of operation has most likely resulted in greater landings, as discussed later, it has not resulted in greater economic efficiency.

In 1981 there was increasing concern with the continuing increase in fishing effort, poor economic returns to fishermen and a large latent effort (Rohan et al. 1981). These conditions existed in spite of the establishment of a limited entry fishery in 1976, and the introduction of constraints on participation since then. These constraints included surrendered barramundi endorsements being lost to the fishery, non-transferability of endorsements, limits on net head rope length, area and seasonal closures, and constraints on the placing of net. It was thought that such constraints would decrease the rate of increase in effort.

In response to concern with increasing effort, low average returns per operator and high latent effort, a net endorsement buy-back was introduced in 1982. Along with input constraints this management proposal was put up by a Canadian consultant economist, Professor Parsival Copes, of Simon Fraser University, in 1977.

Although there appears to have been some confusion over what the buy-back would achieve, it was recognised that the effect of buy-back would be to remove latent effort. The price offered to fishermen was consistent with such a limited objective. The offer price was such that anybody having any more than a minimal involvement in the fishery would prefer to maintain their operations, at least until some time in the future when it was expected that transferability of net endorsements would be allowed. The use of buy-back in the Northern Territory barramundi fishery is discussed later.

Data Collection

The data discussed later were taken from responses given in a survey of barramundi operators in late July and early August 1984, licence applications, and fishermen's monthly returns. The survey data were collected from fishermen in the field using a pre-constructed personal questionnaire.

Because of the difficulty in contacting fishermen, it would not have been possible to apply any sort of equal possibility sampling frame. Accordingly fishermen were interviewed as and where possible. This has, no doubt, resulted in bias in the information obtained, but was considered preferable to alternatives such as a mail questionnaire, or contacting fishermen in the off-season. Because of the limitations of the transport used a disproportionate number (12 or 86% of population) of shore-based operators were interviewed (9 boat-based were interviewed). Where appropriate the data has been weighted accordingly.

Distribution of Landings and Effort

The purpose of this section is to give an understanding of the present status of the fishery. This is done through an examination of catch and effort figures according to year, season, whether operations are boat- or land-based, and according to whether catch has been

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taken over mud-flats or in the rivers. Such analysis is useful as a basis for understanding existing management controls and for considering the possible effects of changes in management to the fishery.

Yearly distribution in barramundi and threadfin, landings effort, and returns for 1972 through 1985 are shown in Table 1. While landings and effort between years is highly variable, since 1977 the catch and effort values have remained steady. Prior to 1977 the catch, effort and catch per unit effort figures are indicative of a developing fishery, with both catch and effort increasing and catch per unit effort falling.

February and March. This is possibly due to shore-based operators not being able to get into the fishing grounds during the wet, and logs and other jetsam washed down by flood waters making it difficult to maintain nets set in the rivers during these months.

The fall-off in landing in June through September may be due to any of a variety of causes. These could include a fall in water temperature, and changes in water salinity during the inter-monsoonal dry. Consequently there may be less fish movement, movement above the closure lines, or movement out from the rivers to the mud-flat areas. Certainly the data in Table 4 are consistent with greater relative access to barramundi over the mud-flats in the latter 2 months of the season. It is also possible that the fall-off in landings may be related to a relative fall in available fish, with most of those size-classes targeted by the mesh size having been taken earlier in the season.

Table 1. Landings and returns by year.

Year	Effort 100 m net days	Barramundi (kg)	Threadfin (kg)	Barramundi CPUE (kg)	Barramundi Returns $	Return PUE $	CPIA(a) RPUE $
1972	17 259	381993	93900	22.1			
1973	21 014	431266	167550	20.5			
1974	22 774	655976	178950	28.8			
1975	15 741	432280	138600	27.5			
1976	(b)	973785	154300	(b)			
1977	72 020	1054053	375400	14.6			
1978	95 879	820045	436800	8.6			
1979	100 714	745345	500596	7.4			
1980	77 303	569027	426556	7.4	1 476 534	19.10	20.90
1981	66 442	762101	488237	11.5	2 034 020	30.61	30.61
1982	95 397	856118	507357	9.0	2 686 584	28.16	25.51
1983	87 078	604575	459954	6.9	1 964 889	22.56	18.33
1984	71 625	621917	428420	8.7	2 141 319	29.90	22.72
1985	64 212	593321	354654	9.2	2 122 751	33.06	24.10

(a) CPIA = Consumer Price Index Adjusted with 1981 as the base year.

The returns column presents the total gross returns for barramundi and threadfin salmon. As the returns from other species were not significant they have not been included. The annual returns per unit effort were calculated by dividing returns by effort. Thus, in 1985 the average return/100 m of net per day was A$33.06. For a fisherman operating 1000 m of net (or 10 units) the average daily return was $330. While returns per unit effort have been highly variable from 1980 to 1985, whether in nominal or real terms, there has been no discernible change in returns per unit effort.

There was a large seasonal variation in average monthly barramundi and threadfin salmon landings and effort for 1980 to 1985. There is a peak in landing and effort for May. There are several likely explanations for the rise from the beginning of the season to May, and the drop-off after May through the rest of the season.

The lower landings early in the season are most likely due to the monsoonal wet. The resulting flooding is likely to result in a greater dispersion of fish. In addition, effort in the rivers is down for

Differences Between Land- and Boat-Based Operators

A number of production characteristics for the barramundi fishery according to whether the operator is land- or boat-based are presented in Table 2 based on fishermen's monthly returns for 1982 to 1984.

The data show the fishery is dominated, in terms of catch, effort and returns, by boat-based operators. Given the substantially larger number of boat-based operators this difference is not surprising. The returns are more interesting when they are examined according to an average operator.

There is little difference in average barramundi landings between boat- and land-based operators. Boat-based operators did average a larger threadfin

Table 2. Returns according to type of operation.

	Land-based Total	Boat-based Total
1982		
S/B (a)		
N	15	64
Barra. kg	135588	722090
T. Salm. kg	49794	457563
Income $	397344	2289240
Effort (b)	12544	82853
B/UE (c) kg	10.81	8.72
Inc/UD(d)$	36.68	27.63
1983		
S/B (a)		
N	14	55
Barra. kg	123764	480811
T. Salm. kg	32573	427433
Income $	351037	1613852
Effort (b)	13417	73661
B/UE (c)kg	9.22	6.53
Inc/EU(d)$	26.16	21.91
1984		
S/B (a)		
N	9	45
Barra. kg	118810	498334
T. Salm. kg	42161	386609
Income $	294900	1807974
Effort (b)	10959	60688
B/UE (c)kg	10.84	8.21
Inc/UE(d)$	26.91	29.79

(a) Salmon/barramundi; (b) hundred metre net days; (c) barramundi/unit effort; (d) income/unit effort.

salmon catch, and a correspondingly higher threadfin/barramundi ratio than land-based operators. This difference in species landings is most likely due to boat-based operators applying proportionally, and in total, more fishing effort to the foreshore and mud-flats than did the land-based operators.

In hundred metre net days (HMNT) of effort the average boat-based operator exerted more fishing pressure than land-based operators. As a river set net has a longer drop than that used over the mud-flats, there is most likely little difference in effective effort between the two types of operators.

Over the 3 years shown in Table 2 average annual earnings for boat-based operators was $34 988. For land-based operators average annual returns were $27 493. On average, boat-based operators grossed $7500 or 27% more than that reported by land-based operators.

When return to effort is examined, these results are turned around. Land-based operators reported a higher return per unit effort than boat-based operators for 2 of the 3 years. The average yearly return per unit effort for boat-based operators was $26.42, which is a 4% fall in the $27.45 earned by land-based operators.

A further analysis of costs and returns for 1984 according to whether the operators were land- or boat-based is presented in Table 3. On average, land-based operators fished more days than boat-based operators. What is particularly interesting is that land-based operators netted higher returns than the boat-based operators. While these figures indicate that in 1984 land-based operators were more efficient than boat-based operators, it is difficult to say by exactly how much, and whether this relationship would hold over the long term. It is likely, though, that the difference is greater than that shown. The gross returns for the land- and boat-based operators who were interviewed was $38 000 and $50 000, respectively. Those figures are 15 and 25% higher than that for all of the operators in each type of operation.

There are a couple of observations which may be important in explaining and understanding the difference between boat- and land-based operators. While boat-based operators can get into fishing areas earlier than land-based operators, being boat-based can be a disadvantage. A land-based operator can continue operating while landings are trucked to the fish buyer and stores are collected. In most, though not all cases, a boat-based operator will need to discontinue operations. The other point is that there has been no allowance for depreciation. As this is likely to be higher for boat-based operations, then the relative net

Table 3. Daily costs and returns for 1984 by type of operation.

		Refit Capital & Fuel Costs							
		Refit & Capital Costs							
Type of op.	Days fished	Refit(a) $	Capital(b) $	Daily $	Daily fuel $	Total cost $	Gross return $	Cost less return $	Total net (a) $
Land	159	8125	2550	67	31	98	251	153	24327
Boat	140	14887	9857	177	56	233	357	124	17360

(a) Includes costs due to cyclone damage (b) interest rate used was 15 %; no allowance was made for depreciation (c) labour food and administrative costs are not included.

return received by land-based operators would be expected to be greater than that calculated.

In 1984 and 1985 catch per unit effort (CPUE) of barramundi was higher in the rivers than over the mud-flats (Table 4). In spite of the difference in CPUE, more barramundi is taken over the mud-flats than was taken within the rivers. As mentioned earlier, the fall-off in CPUE in the rivers is indicative that barramundi are moving elsewhere, including out over the mud-flats, or above the closure lines. These figures are also consistent with the earlier observations on the variation in CPUE between boat-based and shore-based operators.

but need not, include the purchase of the fishing equipment associated with the licence.

A buy-back can be funded by an outside body or by those remaining in the fishery. There are definite financial and equity benefits in a buy-back being financed by those remaining in the fishery. In addition a buy-back levy on those remaining in the fishery will act as a 'stick' to complement the 'carrot' offered by the buy-back price.

In introducing the Northern Territory buy-back program other parts of the existing management program were maintained. Of particular importance to the program was: the limit on the amount of net that any one endorsement holder could operate; and the maintenance of non-transferability of endorsements.

Table 4. Average monthly CPUE 1984 and 1985: Mud-flats and rivers.

	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Total Weight (kg)	Effort (HMND)	CPUE (kg)
Mud-flats	8.82	6.70	5.67	9.47	8.60	7.26	9.71	9.42	678636	77944	8.71
Rivers	4.7	12.98	17.06	15.11	12.63	9.05	8.63	8.07	341631	27460	12.44

Participation in Buy-Back

In June 1976 the barramundi fishery was established as a limited-entry fishery. At the time 154 fishermen held endorsements to operate inshore gillnets and to land barramundi. In 1979, just prior to the 1980 season, barramundi entitlements were made non-transferable. At that stage there were 117 entitlement holders, which was a 27% decrease in the number of endorsement holders since the creation of the limited entry fishery. With the introduction of buy-back in 1982, the number of entitlement holders had fallen a further 25% to 85. In 1983, there were 69, in 1984, 54, 1985, 48, and 1985, 47.

Generally buy-backs have been seen as a means of reducing effort in a fishery which has become over-capitalised (Crutchfield 1961). Unless a taxing system is introduced to capture and hold the rents which have been released through a buy-back, the benefits are likely to be of a short-term nature. In spite of this shortcoming, managers and industry believed the benefits from buy-back to be sufficient to warrant its introduction to the Northern Territory gillnet fishery. In addition a buy-back is currently in operation in the northern prawn Declared Management Zone, in northern Australia, and is under consideration for the South Australian rock lobster fishery, and the Tasmanian abalone fishery.

There are a number of different forms that a buy-back can take (Campbell 1985). Generally, a buy-back involves the purchase of a property right by the original holder of the property right. In the case of a fishery it involves the buy-back of the right to fish (a licence or endorsement) or part of that right. It may,

The net buy-back was introduced into the fishery at the beginning of the 1982 season and ended by the middle of 1986. Over the duration of the scheme the number of endorsement holders was cut back from 85 to 40. The price paid to fishermen per metre of endorsed net, and the fees paid per fisherman per metre of endorsed net steadily increased over the duration of the buy-back scheme until 1986 when there was a substantial increase in both rates.

Initially the aim of the buy-back was limited. In offering only to buy the net endorsement, but not the boat, net, processing gear and freezer, the program was not intended to remove active participants. The catch and effort data to the end of 1985 is consistent with this limited expectation. At the end of 1985 a deliberate decision was made to remove fishermen who had demonstrated a lower level of involvement in the fishery. As a consequence, based on previous effort and landings, the price offered to fishermen was increased.

While there was a decrease of nearly 20% (16) in the number of operators in the first year of the scheme, this had fallen to only 10% (6) in 1984, and 2% (1) in 1985. The original buy-back was directed at removing underutilised net endorsements. The fee and price rate was appropriate to this objective. By the end of 1985, on average, those remaining in the fishery had a high level of involvement. The new rates were in recognition of this change.

Based on the data presented in Tables 5 and 6,

observations can be made in regard to how the buy-back was carried out, who participated and who was left in the fishery. While it was not a deliberate strategy, the approach taken, of offering a minimum price, and only increasing the price when necessary, was most likely the most cost-efficient way to go about withdrawing latent, and later, actual effort (Table 5). The outcome was to put the government into a buying position similar to that of a discriminating monopsonist.

apparent, though, that the type of participant who left the fishery in 1986 is different to those who left previously. The difference appears to be due to the type of operator left in the fishery by the end of 1985. Whilst there has been no increase in catch per unit effort up to the end of 1985, preliminary figures for 1986 show that there has been an increase in catch per unit effort. This has been in spite of a fall in overall landings.

Table 5. Buy-back levies and payments ($ Aust) 1982 to 1986.

Year	1982	1983	1984	1985	1986
Levy/100 m held	37.5	60	60	60	200
Payment/100 m sold	400	1000	1000	1000	≥3000
Bonus if all sold			50%	50%	25%

Table 6. Barramundi catch and effort of 1985 and 1986 endorsement holders.

	1982		1983		1984		1985	
	Barra (kg)	Effort (HMND)	Barra (kg)	Effort (HMND)	Barra (kg)	Effort (HMND)	Barra (kg)	Effort (HMND)
'85 Buy-Back	13239	1478	10622	1533	12423	1400	—	—
(a) Remainder	5966	660	4511	597	4265	740	—	—
'86 Buy-Back	12921	2125	10666	1600	12770	1390	13656	1471
(b) Remainder	7450	231	6136	795	7936	1145	6727	858

(a) The first row gives the average catch effort of those left in the fishery in 1985. The second row is the average catch of all others. (b) The first row gives the average catch and average effort of those left in the fishery at the completion of buy-back in 1986. The second row is the average catch and average effort of all others.

The success of the approach used depends on several conditions being met. These include the potential outgoer not expecting a higher price to be offered in the future, that there is non-transferability of endorsements, and that there is no expectation of higher returns per unit of effort. The failure of any one of these conditions being met would likely diminish the number of individuals participating in buy-back. These conditions were met in the Northern Territory barramundi buy-back.

In terms of barramundi landings and effort there is a substantial difference between those who participated in buy-back and those who remained in 1985 and at the end of the buy-back in 1986 (Table 6). It is somewhat surprising, though, that there is so little difference between the performance of those who remained in 1985 and those who remained at the end of the buy-back in 1986.

It is apparent that the price offered to participants prior to 1986 discriminated in terms of the type of participant. The price offered in 1986 did not discriminate in the type of buy-back participant. It is

Discussion

The Northern Territory barramundi fishery differs from most other inshore fisheries in Australia and, I suspect, elsewhere because of the quality of data associated with the fishery. As a consequence of this data base insights on the effect of different management regimes on the fishery can be observed. Accordingly, the fishery has an importance for all of those involved in barramundi management.

Following the completion of the buy-back it remains to be seen now just how long the improvement in catch per unit effort remains. It is to be expected that the remaining fishermen will either increase their effort or increase the technical efficiency of the effort used. In either case there will be an increase in costs. One result of the decrease in numbers will be a decrease in enforcement and possibly management cost. Further, the decrease in operators due to buy-back and endorsement transferability will make other management options, such as individual transferable catch quotas (Campbell 1985), and localised fishing rights, more attactive.

In regard to local fishing rights, as against a right to fish anywhere along the coast, as occurs now, the difference in outcomes between boat-based and land-based operations is important. An argument against localised rights is that for fishermen to do well they need to be able to shift their operations with changing conditions. While there are strong conceptual arguments against such a requirement, the fact that land-based operators, who in most cases are confined to a fixed location, are doing better, gives a strong practical argument against the need to be able to shift operations.

The background information presented here in giving a better understanding of the Northern Territory barramundi fishery is expected to be of assistance in future decisions on barramundi-based fisheries.

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Distribution and Fishery of *Lates calcarifer* in India

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SEA BASS, *Lates calcarifer*, is widely distributed along the coasts of the Indo-Pacific Region, and in India this fish supports a commercial fishery mostly in estuaries, brackishwater lakes and lagoons. It is landed in very limited quantities from coastal waters (Raj 1916; Chacko 1956; Devasunadaram 1954; Jhingran and Natarajan 1969; Jhingran 1982).

Studies exclusively on the fishery of *Lates calcarifer* are lacking, and only a very few detailed studies have been carried out (Jones and Sujansingani 1954; Chacko et al. 1953; Jhingran and Natarajan 1966, 1969). Most of the studies relate to the biology and culture of sea bass (Ghosh 1971, 1973; Ghosh et al. 1977; Hora and Nair 1944; Kowtal 1976, 1977; Menon 1948; Mukhopadyay and Karmakar 1981). Gopalakrishnan (1972) has dealt with the taxonomy and biology of *L. calcarifer* along with other culturable tropical fishes. In this paper the distribution and fishery of *L. calcarifer* are reviewed. The future prospects for the exploitation of the resource are indicated and recommendations are made for further development of the fishery based on studies of the population dynamics of this species.

Distribution

Lates calcarifer is distributed in the northern part of the Indo-Pacific region, southward to Australia and westward to East Africa in the coastal waters (Day 1958; FAO 1974). In India this species occurs along the coastal waters in small quantities and in estuaries, lagoons, backwaters, and lower reaches of rivers adjoining estuaries in good abundance. A certain fraction of the population, especially very large, mature adults, appear to avoid lagoons and inhabit mostly the coastal inshore waters. The rest of the population, mostly young ones, occur in less saline intertidal zones, estuaries and other backwaters. The occurrence of this species in offshore waters has not been reported from India. The sea bass breeds in the sea and the fry enter the Thakuran, Matlah and lower stretches of Hoogly Estuary during May–October in West Bengal and during July–August in Chilka Lake near the lake mouth in Orissa (Jhingran and Natarajan 1969).

Stray fingerlings, measuring 50–70 mm occur in the northern sector of Pulicat Lake during May–June (Rao and Gopalakrishnan 1975). Early larvae 4–6 mm have been reported from the intertidal zone of the creeks of Kakdwip (Mukhopadhyaya and Varghese 1978). As observed from the fishery, 46.8% of the *L. calcarifer* resource is distributed in the northern sector, 45.1% in the central sector and only 8.1% in the southern sector of the Chilka Lake (Jhingran and Natarajan 1969). Young ones measuring 374 mm and below always occurred in good abundance in Chilka Lake (50% and above). However, during some years fish of the size group 375–599 mm have been abundant. The size groups larger than the latter are distributed sparsely and their percentage distribution decreases with the increase in size and age (Jhingran and Natarajan 1969). Sometimes this species occurs in rivers in fresh water (Anon 1951).

Migration

Though this species is considered to be anadromous in Thailand (Smith 1945), migration is not highly pronounced in India. Localised migration of lesser magnitude for the purpose of feeding and breeding has been reported by Chacko (1949a) in Coleroon River mouth, ascending up to the Lower Anaicut a distance of nearly 50 km. In Krishna River, sea bass ascend for a distance of 50 km (Chacko 1949b).

On the southeast coast of India, at Muthpet, Tamil Nadu, the young ones migrate into saline swamp (Chacko 1949c). In the Godavari and Krishna rivers this fish has been reported to migrate up to 130 km from the sea (Anon 1951) and all these migrations into the freshwater rivers, brackishwater lagoons, lakes and swamps are for shelter, feeding and growth. However, the breeding migration is not clear. During breeding seasons (June–July and January–March for Chilka stock and October–December for Tamil Nadu stock), the potential breeders are considered to migrate to the adjoining sea for spawning (Jhingran and Natarajan 1969; Chacko 1949c; Jones and Sujansingani 1954).

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Fishery

Fishing Grounds, Craft and Gear

The brackishwater lakes and estuaries of major rivers of India are the important fishing grounds for this species. The important lakes are Chilka Lake in Orissa, Pulicat Lake in Tamil Nadu and Vembanad Lake and its connected backwaters in Kerala. Among the estuaries, the Hoogly-Matlah estuary in West Bengal, the Mahanadi Estuary in Orissa, the Godavari and Krishna estuaries in Andhra Pradesh, the Cauvery Estuary in Tamil Nadu and the Narmada and Tapti estuaries in Gujarat support the fishery to a considerable extent.

Plank-built boats, dugout canoes and catamarans are employed in the fishing operations. Some of the craft are now mechanised. The plank-built boats are mechanised with inboard engines and the others with portable outboard engines. These fishing craft are of various types and sizes with different vernacular names. The fishing gear of Chilka and Pulicat Lakes has been described and discussed by many workers (Hornell 1924; Mitra 1946; Anon 1951; Devasundaram 1951, 1954; Jones and Sujansingani 1952, 1954; Job and Pantulu 1953; Chacko et al. 1953; Mohapatra 1955; Mitra and Mohapatra 1957; Jhingran and Natarajan 1969; Krishnamurthy and Rao 1970). There are 13 well-defined nets of three types (dragnets, gillnets and cast nets) in use in Chilka Lake. Krishnamurthy and Rao (1970) described one shore seine, 8 dragnets, 3 bagnets, 2 fixed nets, 2 stake nets, 1 cast net, long lines and hand lines which are extensively used in Pulicat Lake.

The important gear used include: *Bhekti jal,* a dragnet with bag, in Chilka Lake and *Koduva valai,* a type of gillnet, made of sun hemp twine, in Pulicat Lake. These two nets have been designed with the aim of exploiting the sea bass and are named after the sea bass. The knots of the *Koduva valai* are of reef-knot type which get loosened depending upon the girth of the fish captured. The *Bhekti jal* net catch comprises 59.3% sea bass. The net is 9 m long, 3–4.5 m in depth and provided with rectangular floats and having a knot to knot mesh size of 45–76 mm (Jones and Sujansingani 1954). The other gear used to land sea bass in Chilka Lake are *Khepa jal* (cast net, 6.1%), *Bhida jal* (drag net, with bag, 5.5%), *Noli jal* (gillnet without foot rope, 0.9%), *Patua jal* (drag net with bag, 0.7%), *Khadi jal* (drag net without bag, 0.5%), *Menjia jal* (gillnet with foot rope, 0.2%) etc. In Pulicat Lake *Badi valai* (shore seine), *Peria konda valai* (drag net), long line and hand line and *Barang jal* (gillnet) in Hoogly-Matlah Estuary also land sea bass.

Fishing Methods

Four types of fishing methods (net, impoundment, hook and line, trap) are employed in the brackishwater lakes and estuaries of India.

Net fishing is conducted throughout the year with apparently low fishing intensity during October–December, contributing 50–66% of annual production of Chilka Lake in which the sea bass constitutes 2.1% of the production. The drag nets have been reported to land the bulk of the catches. Impoundment fishing is conducted by erecting large impoundments with the help of split bamboos in shallow areas of lakes and are operated during October–February, accounting for 13–22% of the lake's annual production. Hook and line fishing is conducted using monofilament as snoods with No. 6–10 hooks in long lines. Monofilament hand lines are employed using prawns and fish as bait for *L. calcarifer*, threadfins and other perches. Trap fishing is conducted with traps mostly for prawns during March–September in Chilka Lake. Perch traps made of bamboos are extensively used in Palk Bay and Gulf of Mannar in Tamil Nadu.

Catch Statistics

Estuarine Fishery

The catch of *L. calcarifer* during 1964–76 from Hoogly-Matlah estuary varied between 21 and 283 t and the percentage composition in all fish catches between 0.15 and 3.43. On an average 78.4 t of *L. calcarifer* were landed annually which constituted 0.9% of the total average production.

Annually 179.8 and 466.5 t of fresh and dried fish from Mahanadi estuary are caught (Shetty et al. 1965). *Lates calcarifer* constituted 3.7% of the total production from the estuary. An average annual catch of all fish of 3036.1 t has been reported from Godavari estuary in which the perches formed 6% of the landings (CIFRI 1964). The percentage composition of *L. calcarifer* has not been reported. Venkatesan (1969) reported the estimated total landings of 371 t of fish from six estuaries of Tamil Nadu on the southeast coast of India in which sea bass constituted 14.5 t or 3.9% of the total catches during 1967–68. The information on the catch statistics on sea bass is not available for the other estuaries along the Indian coasts.

Lake Fishery

Several workers have studied the fishery of Chilka Lake since 1930 (Mitra 1946; Devasundaram 1954; Jones and Sunjansingani 1954; Jhingran and Natarajan 1966, 1969; Sengupta and Patro 1970). Detailed studies on the important fisheries of Chilka Lake were carried out by Jhingran and Natarajan (1969) during 1957–65. The estimated annual average fish yield was 3663 t in which sea bass constituted 5.9% of the total catches. The yield per hectare for the lake varied from 25.1 to 43 kg with an average of 35.3 kg/ha and the calculated yield of *L. calcarifer* was about 2.1 kg/ha.

The *Lates calcarifer* fishery of Chilka Lake showed extreme fluctuations and the highly successful fishery in 1964 with landings of 749 t has been ascribed to

Table 1. Estimated total fish catch and composition of *L. calcarifer* in Chilka Lake. Source Jhingran and Natarajan (1969).

Year	All fish catch *(t)*	*L. calcarifer* total catch *(t)*
1957	4,455.7	174.3
1958	3,837.9	136.2
1959	3,796.7	150.9
1960	2,603.6	102.2
1961	2,861.2	55.3
1962	3,896.9	113.0
1963	3,928.4	294.5
1964	3,214.0	748.6
1965	4,375.6	163.3

continuous lakeward ingress during the period January-June and October-December (Table 1). In impoundment catches, the size range 150–374 mm formed 65.3%, 375–599 mm 32.4% and 600–749 mm formed 2.2%.

Population Dynamics

Length-Weight Relationship

De (1971) recorded a strong positive correlation of these two parameters at early stages of life of *L. calcarifer*.

Ganguly et al. (1959) studied the length–weight relationship of *L. calcarifer* in a natural population in relation to other morphometric characters. The length–weight relationship of *L. calcarifer* is Log W = –5.0188 + 3.0342 Log L, r = 0.9988. Patnaik and Jena (1976) have worked out the length–weight relationship of the species of Chilka Lake.

Mortality Parameters

NATURAL MORTALITY COEFFICIENT (M)

The natural mortality coefficient in *L. calcarifer* estimated by the 'Independent Method' (Pauly 1980) from the formula Log M = –0.0066– 0.279 × Log L ∞ (cm) + 0.6543 Log K + 0.4634 × Log T (°C) is 0.45.

TOTAL MORTALITY COEFFICIENT (Z)

The total mortality (from fishing, natural as well as migratory loss) computed separately for year II/I and III/II age-groups and averaged for the period 1958–65 by Jhingran and Natarajan (1969) was estimated at 63%. If the annual average mortality rate A is 0.63, then the average survival rate is 0.37 (i.e. $S = 1–A$; 1–0.63 = 0.37) and the total instantaneous mortality coefficient Z is Log_e of S i.e. –0.99. With sign changed Z is 0.99.

FISHING MORTALITY COEFFICIENT (F)

The average annual fishing mortality coefficient F is $Z–M$; i.e. 0.99–0.45 = 0.54.

Recruitment

Maturing and mature individuals of *L. calcarifer* have been observed during April–July in Chilka Lake. Peak period of breeding has been inferred to be June–July and spawning is believed to take place in the inshore waters (Raj 1916; Jones and Sujansingani 1954; Jhingran and Natarajan 1969; Gopalakrishnan 1972). It is very likely that another spawning in Chilka *L. calcarifer* may be around the period January–March. The recruits to Chilka fishery in July–August are traceable to this period. Recruitment to the fishery takes place at 162 mm (modal value) and again in July–August at modal sizes 112–162 mm during 1958–65 (Jhingran and Natarajan 1969). The latter recruits are especially dominant in certain years. The age at recruitment is 0.378 year and age at first capture is 0.65 year.

Yield per Recruitment

The yield per recruitment of *L. calcarifer* for different fishing mortality coefficient *(F)* at the age at first capture 0.65 year for three different *M/K* ratios i.e. 1.5, 2.0 and 3.0, is given in Fig. 1. For the prevailing M/K ratio 2.0, the fishing mortality coefficient which can bring in the highest yield of 598.4 g is 0.3 which is far below the highest average fishing mortality coefficient during 1958–65, i.e. 0.54, and this is so in the other two M/K ratios also. Jhingran and Natarajan (1969) observed that, in spite of the increase in number of fishermen over the years, the effective fishing effort has not substantially changed resulting in a stabilised yield within a certain range. The quantum

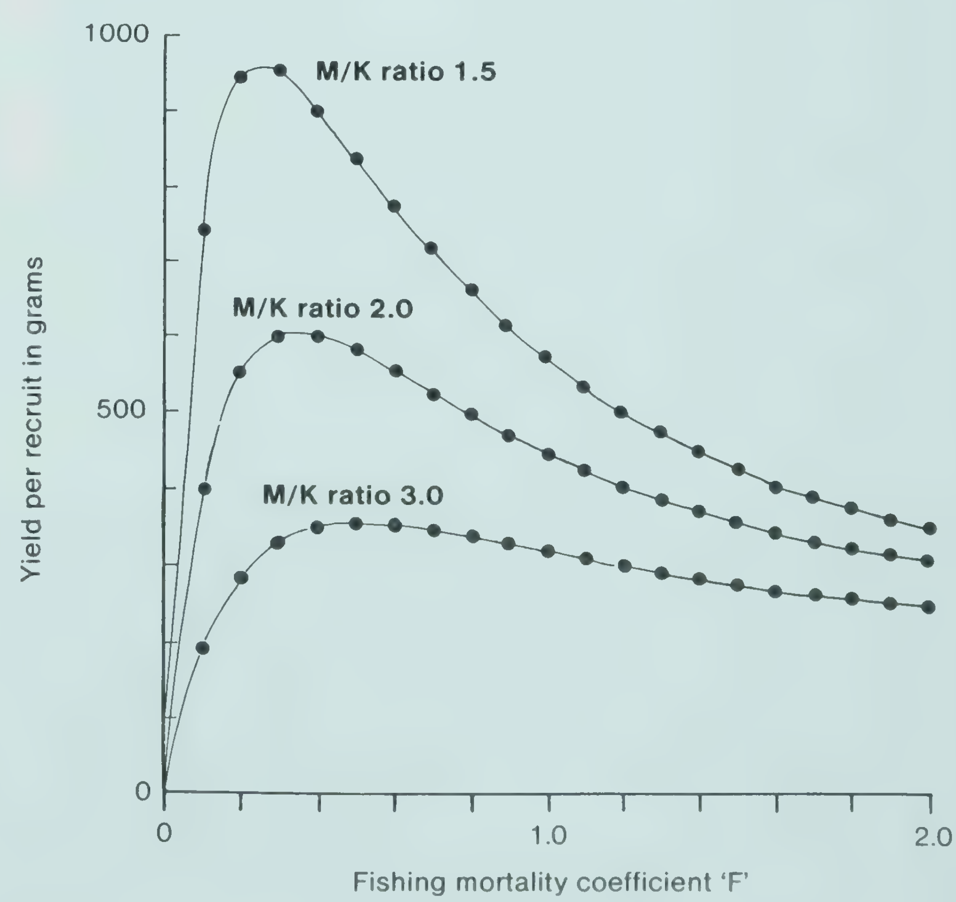

Fig. 1. Estimates of yield per recruit (in *grams*) of *Lates calcarifer* for three different M/K ratios indicated at different fishing mortality coefficients (F) and prevailing age at first capture, i.e. 0.65 year.

of fishing effort, however, far exceeds the optimum level and this is reflected in low mean age/size.

The annual mean length in fishing during 1958–65 varied in the range 234–562 mm with an overall mean length for the entire period at 405 mm. The minimum size at maturity was 425 mm which is fairly close to overall mean length. As the age at first capture is anywhere below 405 mm, the prevailing fishing intensity is much higher than the required optimum level. Considering these points it was rightly suggested by Jhingran and Natarajan (1969) that any additional input of fishing effort is therefore not warranted.

Optimum Age of Exploitation And Potential Yield Per Recruit

The optimum age of exploitation (t_y) is defined as the age when the brood attains its maximum weight, and potential yield *(Y)* is the quantity corresponding to this weight as a function of infinite fishing intensity (Beverton and Holt 1957). The optimum age of exploitation and potential yield for recruitment estimated by the method of Krishnankutty and Qasim (1968) are 3.82 years and 961 g.

Discussion

Present Status of Exploitation

The foregoing observations, namely low mean age, low age at first capture and high rate of exploitation all reflect that the Chilka Lake stock of *L. calcarifer* is subjected to high fishing pressure. Any improvement in yield could be expected only when the age at first capture is increased by manipulation of gear selectivity for which there is little scope in the tradition-oriented fishing practices in Chilka Lake. Substantial quantities of *L. calcarifer* are obtained in impoundment fishing, forming 8.3% whereas the species constituted only 2.1% in net fishing. The question of mesh size regulation under these circumstances has no relevance. However, it may be pertinent to suggest that fish smaller than 150 mm occurring in the catches must be saved and returned to the lake alive. Marketing and local consumption of these sizes must be banned as a first step in the direction of improving the stock and fishery.

However, it is encouraging to note that since this species depends on the sea for breeding, a certain fraction of the population, especially very large size groups, appear to avoid lagoons and they no longer come under the fishing pressure in lagoons. They act as reserves in providing constant recruitment to make good the depletion in the fishing area. However, in some years there has been heavy recruitment. Depletion of this stock because of overfishing in estuaries/lagoons is a remote possibility. This stock bears analogy, in some respects, to a coastal or 'fringe' fishery where part of the population is unfished and beyond the coastal gear (Jhingran and Natarajan 1969).

Prospects and Recommendations

It is well known that increase in production of *L. calcarifer* from the capture fisheries sector is very much limited as the fishery is sustained mostly by immature fish aged less than 2 years. Most of the recruits suffer fishing mortality without spawning even once in their lifetime and only a very few grow into adults and return to sea for breeding. If the fishery has to be improved the age at first capture must be sufficiently well above the minimum size at first maturity (425 mm). As this is highly unlikely, only the size regulation as suggested already may be implemented to protect the fishery from irrational exploitation. Further, to augment the sea bass natural recruitment, sea ranching of this species may be attempted by standardising a series of techniques on breeding by natural as well as induced methods under captivity through maintenance of a series of brood stocks and rearing of the larvae and young ones in well-established hatcheries to obtain high survival rates. The young ones thus reared may be released in the wild in good numbers in addition to supplying the seed regularly for commercial culture in ponds and other natural and constructed impoundments. Follow-up action may be taken to assess the impact of sea ranching of this species in the overall production. Attempts may also be made to stock this species in freshwater ponds, lakes and reservoirs. This species may not breed and get well established in fresh water as in the case of *Hilsa ilisha* and *Rhinomugil corsula,* but it has been reported to grow faster in fresh water (Alikunhi 1957; Ghosh 1971). This may be expected to form a good game fish like salmon in lakes and reservoirs.

Studies on *Lates calcarifer* are very limited in India, probably because this species does not constitute a large commercial fishery in coastal waters except in lagoons and estuaries. National support through organised research programs is limited and considering the quantum of the catch and its economy there is no government-sponsored program operated exclusively on *L. calcarifer*. However, because it is a good quality table fish, and fetches a high price, and considering the prospects for culture, it is essential that studies be initiated through well-planned research on the biology, artificial propagation and culture in fresh and salt water.

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Culture — Spawning

Induction of Spawning of Sea Bass *(Lates calcarifer)* in Thailand

Sujin Maneewong*

In the past, Thai fish farmers had to collect sea bass fry from the wild for stocking in ponds or cages. The supply of fish seed varied from year to year thus limiting the growth of the culture industry in Thailand. To overcome this seed supply problem, induced spawning of sea bass was first studied and tried at Songkhla Fisheries station in 1971.

In 1973, wild sea bass were successfully induced to spawn by artificial means. This was done by hand stripping of eggs and milt at the Songkhla Fisheries Station. The methods of inducing sea bass spawning and propagation of the fry have been improved and developed at the Station, providing leadership in this work. The Station made further progress with sea bass spawning in captivity by using the spawners from cultured broodfish in 1975. Subsequently, the techniques were spread to various fisheries research stations and private hatcheries. In 1977, Rayong Fisheries Station succeeded in sea bass spawning in captivity by using hormone injections. Funds were provided for the construction of sea bass hatcheries under the Fisheries Department. Other Stations (such as Prachuab Khirikhan, Satul, and Phuket) succeeded in inducing sea bass to spawn in captivity the following year.

Artificial spawning of sea bass is now done in both private hatcheries and government fisheries stations located along the coast in Thailand. Two methods for sea bass spawning are used: (1) artificial spawning by stripping running ripe fish from the spawning ground; and (2) natural spawning in concrete tanks.

Stripping Sexually Mature Spawners

This method was first employed at Songkhla Fisheries Station in 1971. Success in producing sequential numbers of sea bass fry was first achieved in 1973. Sexually mature spawners were collected from the wild in the spawning ground. Stripping of egg and milt from the spawners is one of the best methods for collecting an adequate amount of eggs for mass production of sea bass fry. It is also suitable for the hatcheries located near the spawning ground which have no spawners in grow-out culture for broodstock.

To ensure success in seabass spawning using this method, spawning seasons, spawning grounds and spawning time of sea bass in the natural grounds have to be investigated. With this information in hand, the fish farmer is likely to achieve positive results.

The spawning ground of sea bass is near the mouth of the big rivers or lakes, not far from the sea. At Songkhla, the spawning ground is at the mouth of Songkhla Lake where the water is 5–10 m deep. The spawning season is from April to September or before the rainy season. Salinity during the season is about 28–30‰, and water temperature ranges from 27 to 34°C. The spawning period depends on the moon phase, usually occuring 3–7 days after full moon and new moon at 1800–2300 hours. The spawning apparently starts when the tidal current changes and finishes in about 2 hours.

Many kinds of gear are used for catching the spawners, such as drift-net, gillnet, hook and line, cast-nets, etc. Drift-net is the most popular and efficient because even the ripe spawners are caught with it.

Sex Determination

The shape of the male spawner is more slender and generally it is not as heavy as the female spawner at the same total depth. The abdomen of the male does not bulge like the female spawner, and the body depth of the male is less than the female. The scales around anal area of the male become thicker, whereas the anal area bulges out in the female, especially in the spawning season. The female spawner has large quantities of eggs causing the abdomen to bulge. By hand stripping the eggs may flow out from the oviduct opening; in the case of the male, the milt will flow from the urogenital opening.

In general, for stripping, the male is 2–10 kg and the female 3–8 kg.

Spawning Technique

Stripping the spawner from natural spawning grounds requires skill to avoid injuring the eggs or the fish. Selection of a good spawner is made rapidly using the following criteria: active, strong fish; body whole, no missing parts; no obvious disease; no wounds, no obvious abnormalities; likely to have good quantity of sperm or eggs.

Stripping Males

Milt was quickly hand-stripped from male spawners deemed suitable. If necessary, the milt was stored in sealed, dry glass containers or test tubes, and kept in ice. The sperm remained viable up to 3–5 days. Good

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sperm should not be thick and sticky with plasma. When poured from the container, it should flow easily, and under the microscope the sperm should be moving rapidly. Good male spawners yielded between 5 and 10 ml of milt.

Stripping Females

This is usually done by two people working as a team. One person holds the ripe female over a container while the other gently extrudes the eggs by applying pressure on the abdomen from the anterior towards the posterior with the thumb and forefinger; the eggs should flow into the container. Eggs that are ready to be fertilised should have the following characteristics: (a) eggs round in shape and with distended surface (no wrinkles); (b) yolk distributed in whole area of inner egg shell, no perivitelline space; (c) eggs are separated and do not stick together in groups; (d) eggs are transparent, but when in groups they appear to have light yellow or golden colour; (e) eggs float in water at 28–32‰ salinity; (f) diameter of the egg averages 0.8 mm; (g) oil globule is present in the centre with diameter of 0.2 mm; and (h) no yolk vesicle.

Method of Fertilisation

The dry method is usually used for fertilisation. As soon as the ripe female has been stripped, the male spawner has to be stripped for milt. The eggs and sperm are then gently mixed, and sea water (28–32‰) is added and stirred gently again. The eggs then have to be washed repeatedly with clean sea water.

The fertilised eggs are put in vinyl plastic bags with some sea water (28–30‰) and transferred to a hatchery. The capacity of the bag is about 20–25 l, 7–10 l of sea water and 200 000–300 000 fertilised eggs without aeration. If the hatchery is far from the spawning ground, the bags should be aerated. Before putting the eggs into the hatching tank, the unfertilised eggs, which sink to the bottom, have to be taken out and fertilised again. If necessary, the eggs are disinfected with 5 ppm acraflavine before placing in the hatching tanks.

Stripping by Hormone Injection

The males that are collected from the spawning ground do not usually need hormone injections. However, for female spawners, the eggs have to be checked before stripping. If the eggs are in a good, ripe stage, hormone injections are not needed.

Synthetic hormones (HCG, Puberogen and Pregnyl) and pituitary glands are commonly used for injection. The most popular hormone is HCG mixed with pituitary gland of sea bass. Dosage ranges between 50 and 500 IU/kg (body weight) and 2–4 doses of pituitary gland (Tables 1 and 2).

Natural Spawning in Concrete Tanks

This is the best method for commercial scale sea bass spawning because considerably larger numbers of fish seed can be produced. Natural spawning of sea bass in a controlled environment was first done successfully in 1975 at Songkhla Fisheries Station using cultured broodstock.

Source, Collection and Selection of Spawners

Parent fish are raised from the juvenile stage in cages. These can come from fry originally collected from natural waters or from larvae and fry spawned in the hatchery. There is not much selection at this stage, except for regular grading of the growing fry. When this stock reaches juvenile stage, the healthy ones that grow very fast are usually separated to be reared as future broodstock. A second selection is done after the first and second year for the healthy and fast-growing individuals. All these stages are still being reared in netcages in the sea.

Table 1. Induced spawning of sea bass by hormone injection in 1974.

Specimen No.	Body weight (kg)	Time	HCG (IU)	Pituitary (doses)	Remarks
1	5.2	1000	2500	—	
		2200	2500	—	
		1000	2500	—	
		1100	—	—	Dead, some parts showed ripe eggs. Sperm added and 10% fertilised.
2	5.0	0830	2800	—	
		2030	2800	—	
		0830	3000	—	
		2030	—	—	Killed, found some ripe eggs.
3	5.0	0945	3000 +	2 doses	
		2145	3500 +	4 doses	
		2400	stripped	—	All running ripe eggs. 70% fertilised eggs. Hatched out 80%.

Table 2. Duration of embryonic development in sea bass (27°C prevailing temperature).

	Embryonic stage	Period (hours,	min)
(a)	Fertilised egg	0,	0
(b)	One-cell	0,	35
(c)	Two-cell	0,	38
(d)	Four-cell	0,	44
(e)	Eight-cell	1.	03
(f)	32-cell	2,	12
(g)	64-cell	2,	43
(h)	128-cell	2,	55
(i)	Pre-blastula	3,	11
(j)	Blastula	5,	32
(k)	Gastrula	6,	30
(l)	Neurula	8,	32
(m)	Embryo develops head, optic lobes and tailbuds	11,	20
(n)	Heart starts functioning, tail free, body starts to move	15,	50
(o)	Hatching	17,	30

After the second year, some of the males can be identified when they extrude milt with pressure on the belly. However, the females and other males cannot be distinguished at this stage.

The reared broodfish would be ready to start spawning at the end of their third year when they reach 3.5 kg. The best male milt is obtained from 2–4-year-old males, and female fish are not used before their third or fourth year. Approximately 1 month before the spawning season, the parent fish are moved from cages into the spawning tanks.

Round tanks, 10 m in diameter and 2 m deep, are used as spawning tanks at NICA. Approximately 24 spawners are kept in each tank in equal numbers of males and females.

Care and Maturation of Hatchery Spawners

Water supply in the spawning tanks is sea water with average salinity of 30‰. Every other day 80–100% of the total volume of water is drained and replaced with clean sea water.

Fish, sardine or anchovy, with intestines and head removed, are used for feeding the spawners by chopping into bite-sized pieces. Spawners are fed the equivalent of 1% of their body weight once a day in the morning. The excess food which falls to the bottom of the tank should be removed by siphoning.

Generally, during the spawning season, the female will appear with a distended abdomen and swim awkwardly. Approximately 1–2 weeks before spawning, the female fish separate from the school and their feeding activity decreases. The males continue to eat, school, and swim normally.

Spawning Behaviour in Spawning Tank

Natural spawning in control tanks takes place at the same time as natural spawning in open water. Spawning activity always occurs between 1900–2300 hours on the first to the eighth day of a full moon. However, sea bass occasionally spawn after a new moon and during dead tide. The ripe male and female swim together, often turning laterally and hitting the surface of the water before spawning. They spawn continuously 3–5 days/month during spring tide.

Factors Affecting Spawning

Good quality and suitable amounts (1% of body weight) of food should be given to spawners. Overfeeding can result in failure to spawn.

Clean, fresh running water should be used, with adequate dissolved oxygen (not less than 6 ppm DO), and pH range of 7.5–8.5.

Salinity in the concrete tanks should be maintained at between 28 and 32‰.

Disturbances during the spawning season in concrete tanks cause stress to the sea bass.

The breeder should ensure that spawners of appropriate age are chosen, and that the size of males and females is comparable, and that both sexes are evenly represented.

On occasion hormone injections are needed to stimulate the fish to spawn naturally in captivity. The dosage for natural spawning is usually lower than spawning by stripping (about 50–200 IU/kg of body weight).

Hatching

Many kinds of equipment can be used for hatching: 500-l flat bottom or conical fiber tanks; 200-l conical fiber tank, and rectangular concrete tanks (5–30 m^3), filled with sea water (25–32‰). The tanks should be

properly aerated. Density of fertilised eggs in hatching tanks was about 300–600 eggs/l. On occasion, however, we placed fertilised eggs directly in rearing tanks at densities of 30–60 eggs/l.

Normally, cell cleavage would take place about 35 min after the mixing of egg and sperm. The period of hatching of fertilised egg was affected by temperature: for example, larvae hatch out in 17 hours at water temperatures of 27°C and 12–14 hours at temperatures of 30–32°C. The fertilised eggs of sea bass tolerate and hatch out in the salinity ranges of 20–30‰ (i.e. rate of hatching at various levels of salinity is: 5‰, 2.9%; 10, 58.5; 15, 75; 20, 82.3; 25, 83.4; 30, 80.8; 35, 47.

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Induction of Spawning of Sea Bass *(Lates calcarifer)* by Hormone Injection and Environmental Manipulation

Pinij Kungvankij*

SEED supply in culture of sea bass (*Lates calcarifer*) had its beginning in the tidal entry of wild fry into shrimp farms, salt beds and paddy fields. Large-scale commercial production of sea bass in fresh and brackishwater ponds and marine cages is, however, hampered by shortage of fry.

There has been much speculation concerning the spawning habits of sea bass. The spawning season on the west coast of Thailand is April–August (Kungvankij 1984) similar to the east coast (Maneewongsa et al. 1981).

Artificial propagation of sea bass was first achieved in Thailand in 1971 by stripping the ripe spawners collected from natural spawning grounds. In 1973 Wongsomnuk and Maneewongsa (1974) successfully induced cultured broodstock to spawn in captivity by hormone stimulation. Captive broodstock of sea bass were successfully induced to spawn naturally using environmental stimulation (Kungvankij 1981).

Successful large-scale hatchery production of sea bass can be assured if sufficient and consistent supplies of fry are available.

Seed Production

The breakthrough in completion of the life cycle of sea bass in captivity has greatly enhanced the possibilities for mass production.

Broodstock Development

There are two sources of sea bass broodstock: wild-caught adults and those from ponds/cages (2–6-year-old fish averaging 3–5 kg). It is advantageous to use pond or cage-reared broodstock as they are already accustomed to culture conditions. However, when 2–3-year-old culture stocks are not available, wild-caught adults can be used, but they must be first acclimatised under cage or pond conditions for at least 6 months before being used as spawners.

Conditions of Wild Broodstock

Captured fish are placed in transport tanks and taken directly to the hatchery or holding cages. Anaesthetic is not necessary if the fish are shipped in live tanks or in aerated transport containers. Upon arrival at the hatchery, the fish are treated with an antibiotic. If the antibiotic is applied directly into the water, absorption is effected across the gills and the skin of the fish. The recommended concentrations of antibiotics are: 2 ppm for the dripping method for 24 hours and 20 mg/kg of fish for the injection method.

In nature, sea bass are carnivorous and feed voraciously on live fish. However, in captivity, they can be conditioned to feed on dead fish. After recovery from initial injuries resulting from capture, sea bass can be trained to feed on fresh marine fish. It often takes a few days before the fish gets used to the new diet. It is important to throw the feed piece by piece as the sea bass will not eat the food when it settles to the bottom of the tank. The uneaten feed should be removed to prevent water pollution.

Broodstock Maintenance

The fish, whether cultivated or wild-caught, can be maintained as broodstock in cages and concrete tanks.

Floating cages are usually used for broodstock development. Cages made of polyethylene netting materials are attached to GI pipe or wooden frames kept afloat by styrofoam drum and anchored in a calm bay or sheltered marine environment. The size of the cages varies from 10 to 100 m^2 in surface area with a depth of 2 m (dimension: 5 × 2 × 2 m or 10 × 10 × 2 m). Smaller cages are more suitable because they are easier to maintain and manage (such as in changing of net and harvesting). The mesh size of a broodstock cage varies from 4–8 cm. Stocking density of fish is $1/m^3$ of water.

The size of concrete tanks used for holding broodstock depends on the size of the hatchery. It is advisable to use a bigger tank to allow the fish ample space for swimming. Generally, tank volume ranges from 100 to 200 t (5 × 10 × 2 m and 10 × 10 × 2 m). Stocking rate in a broodstock tank is 1 fish/2 m^3 of water. Good water quality in broodstock tanks should be maintained. A water change of about

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30–50% daily is recommended.

Feeds and Feeding

Broodfish are fed once daily with fresh fish given at the rate of 5% of total biomass. Trash fish should be clean and fresh. As a normal practice, feeding is done at about 1600 hours.

Spawning and Fertilisation

SELECTION OF SPAWNERS

The selection of spawners from the broodstock should be done months before the beginning of natural spawning to allow ample time for the fish to be conditioned to environmental and diet controls. Spawners are normally selected based on the following criteria: fish should be active; fins and scales should be complete; fish free from disease, parasites, injury, or wounds; males and females of similar size; spawners should be at least 4–5 kg in body weight and should not be less than 3 years old.

Selected spawners are then transferred to the prespawning tank, in a ratio of 1:1 males:females.

CARE OF SPAWNERS

Immediately after stocking in the pre-spawning tank, feeding is reduced from 5 to 1% of the total body weight and the fish fed once a day to prevent them from getting fat which can result in poor gonadal development. The feed given should be fresh marine fishes such as sardine, yellow stripe threadfin, etc.

Whether the fish are induced by hormone treatment or environmentally manipulated to spawn, they would continue to spawn for 3–5 days after the first spawning provided the environmental factors that stimulate spawning are present (e.g. new or full moon, changes in salinity and temperature, etc.). Since sea bass spawn intermittently (by batch), the same spawners will continue to spawn during full moon or new moon for the next 5–6 months. (Table 1)

Table 1. Monthly fish egg production and hatching rate of sea bass by environmental manipulation at Satul Fisheries Station, Thailand.

	Tank No.	No. of eggs ('000)	No. of yolk fish ('000)	Hatching rate (%)
April 25–28	5	5200	4200	80.7
May 23–27	5	6120	4710	76.9
June 22–25	5	7860	6150	78.2
July 20–24	5	11 240	9450	84.1
July 23–25	4	1350	550	40.7
August 22–26	5	13 510	10 900	80.1
August 24–27	4	2540	1750	68.8
September 22–23	4	1730	1000	57.8
October 20–22	4	2520	1917	76.7
November 19–21	4	390	272	69.7
December 18–21	4	1700	1215	71.5
January 16–17	4	200	86	43.0
February 12–20	4	1438	1140	79.3
March 15–18	4	3770	2960	78.5
April 14–17	5	6640	4890	73.6
May 13–15	5	14 000	11 950	85.4

Spawning

Presently, there are two major techniques employed in mass production of sea bass fry in Southeast Asian countries: artificial fertilisation and induced spawning.

ARTIFICIAL FERTILISATION

Spawners are caught in natural spawning grounds near the mouth of the river or in saltwater lakes like Songkhla where the water depth is about 10–20 m. Gillnets and seine nets are commonly used. Normally, the fishermen will net the fish during spring tide 2–3 days before the new moon or full moon, and up to 5–6 days after the new moon or full moon at about 1800–2200 hours, at the time of the rising tide.

The degree of maturity of the collected spawners should be immediately checked. If the female has ripe eggs and the male is in the running stage, stripping is done in the boat. The fertilised eggs can then be transported to the hatchery for subsequent hatching. In cases where only the male is caught, the milt is collected by stripping into a dry glass container. Milt is then stored in an ice box or refrigerator. The milt can maintain its viability for 1 week in cold storage (5–15°C). The preserved milt should be made available for immediate use when a ripe female is caught.

The dry method of fertilisation is normally used in this case. The eggs are stripped directly from the female to a dry and clean container where the milt is added. A feather is used to mix the milt and eggs for about 5 min. Filtered sea water is then added into the mixture while stirring it and then allowed to stand undisturbed for 5 min.

INDUCED SPAWNING

Two methods are normally used for inducing sea bass to spawn in captivity: hormonal injection and environmental manipulation. Both methods would induce the fish to spawn naturally in the tank. This results in a monthly spawning until the gonads are spent.

Hormone Injection

After stocking sea bass broodstock in the pre-spawning tank for 2 months, the fish are inspected twice a month during spring tide. Ovarian maturity of the female is measured as follows: the eggs are sampled from the female through the use of a polyethylene cannula of 1.2 mm diam. The fish is either anaesthetised or inverted gently with a black hood over the head. The cannula is inserted into the oviduct for a distance of 6–7 cm from the cloaca. Eggs are sucked orally into the tube by the operator as the cannula is withdrawn. The eggs are then removed from

the cannula and egg diameter measurement is made. When the sea bass eggs reach the tertiary yolk globule stage or have a diameter of 0.4–0.5 mm, the female is ready for hormone injection. In males, only those with running milt are chosen.

The hormones usually used to induce spawning in sea bass, and that produce reliable results, are Puberogen and HCG plus pituitary gland of Chinese carp.

Puberogen consists of 63% of follicle stimulating hormone (FSH) and 34% leutinising hormone (LH). The dosage usually applied is 50–200 IU/kg of fish. The fish will spawn at about 36 hours after injection. If no spawning occurs, the second injection is applied 48 hours after the first injection. The dosage of second injection should be double that of the first injection and can also be given 24 hours after the initial injection. The male is usually injected at the same time as the female with a dosage of 20–50 IU/kg of fish. The fish will normally spawn within 12–15 hours after the second injection.

Homogenised pituitary glands of Chinese carp are used at 2–3 mg/kg of fish mixed with human chorionic gonadotropin (HCG) at 250–1000 IU/kg of fish. The time interval of application and spawning are the same as when using Puberogen.

Before injection, the spawner should be weighed and the hormone requirement computed. Spawners should be injected intramuscularly below the dorsal fin. After injection, they should be transferred from the pre-spawning tank to the spawning tank. Twenty-four hours after the first injection, response of the fish to the hormone treatment is often manifested by the swelling of the belly. If the fish is expected to spawn within the next 12–15 hours, a milky white scum (fatty in texture) will appear on the water surface of the spawning tank. If not, a second injection should be given.

Sea bass that are induced to spawn by hormone treatment will always spawn within 12 hours after the second injection. The schedule of injections for subsequent spawning must be synchronised with the natural spawning time of the fish which occurs in late evening between 1800 and 2000 hours.

Environmental Manipulation

Based on field observations and analysis of natural phenomena that occur during the spawning period of sea bass, techniques were developed to stimulate the fish to spawn in captivity. The following steps are necessary: change the water salinity to stimulate fish migration; decrease the water temperature to simulate the decreased water temperature after rain; lower the water level and subsequently add fresh sea water to the tank in order to simulate the rising tide, and follow the moon phase.

Initially, the salinity of water in the pre-spawning tank is prepared at 20–25‰ before stocking the selected spawners. After stocking, 50–60% of water is changed daily until 30–32‰ is reached. This will take about 2 weeks. This will simulate the migration of fish from its growing grounds to the spawning grounds.

Constant monitoring of fish is required to detect pre-spawning behaviour. When the fish is observed to display its silver belly, this is an indication that it is ready to spawn.

The female fish is separated from the school and feeding is stopped 1 week prior to spawning. Two or three days before the new moon or full moon, as the female approaches full maturity, there is an increase in play activity. The ripe male and female swim together more frequently near the surface as spawning time approaches.

At the beginning of the new moon or full moon, the water temperature in the spawning tank is manipulated by reducing the water level in the tank to 30 cm deep at noon time and exposing to the sun for 2–3 hours. This procedure increases water temperature in the spawning tank to 31–32°C. Filtered sea water is then rapidly added to the tank to simulate the rising tide. In effect, the water temperature is drastically decreased to 27–28°C.

The fish spawn immediately the night after manipulation (1800–2000 hours) or if no spawning occurs, manipulation is repeated for 2–3 more days, until spawning is achieved.

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Induced Spawning of Sea Bass *(Lates calcarifer)* in the Philippines

Romeo D. Fortes*

DURING the Regional Workshop on Aquaculture Planning in Asia held in Bangkok, Thailand, on 1–17 October 1975, it was recognised by the representatives of the participating countries that 'the most significant constraint to expansion and intensification of aquaculture in the region is the production and distribution of seed' (FAO UNDP 1976). It was therefore the consensus that seed production and distribution should be initiated and where feasible, attract private industries to establish seed production and distribution centres. Some of the measures identified to remove the above constraint were to pay high priority attention to fish breeding, larval rearing, transport and distribution of seed, and to have technical cooperation among countries in the exchange of expertise, pituitary material for breeding fish, broodfish or even fry (FAO UNDP 1976). The sea bass, *Lates calcarifer*, is recognised as a very important food fish in many countries of the region, and a good species for culture. Practical culture techniques for breeding and larval rearing are needed in order to ensure stability of fish seed supply.

This could bring sea bass culture to the level of other cultured species. The stability of supply of sea bass seed would also provide opportunities for fish farmers to diversify production in approximately 200 000 ha of brackishwater fish ponds in the Philippines and to utilise low saline and unproductive areas for the culture of this highly desired food fish. In addition, sea bass will consume some of the undesirable fishes in ponds.

The first successful spawning of sea bass in the Philippines was achieved in August 1983 at the laboratory of the Aquaculture Department of the Southeast Asian Fisheries Development Center (SEAFDEC-AQD). We therefore need to pursue further work that will refine, modify and simplify the adapted techniques so that these can be used more easily by the industry.

Current Practices In Sea Bass Spawning

Although spawning of sea bass in captivity has been achieved, its practice has not been widely adopted in the country. So far, SEAFDEC-AQD is primarily doing sea bass spawning and larval-rearing using the following methods:

Stripping of Spawners

This method is adapted from the technique used in the Marine Fisheries Station at Songkhla, Thailand, which involves the capture of running ripe male and female fish from their spawning ground. The method involves collecting the milt and eggs into appropriate containers and mixing them immediately employing the dry method of fertilisation. Barlow (1981) described this method in some detail.

Induced Spawning

The sea bass broodstocks are maintained as a community in tanks with aeration and provided with special drainage to simulate the ebb and flow of tides. Constant monitoring of the fish is done to observe pre-spawning activity such as turning laterally during swimming, separation of the female fish from the school, pairing of the male and female fish, and increase in play activity. The fish is then injected with hormones to induce maturation to the stage where ripe eggs and milt can be readily stripped from the parent fish. The state of maturity of the female fish is determined by examination of the egg sample by cannulation after which the fish is injected with hormones at appropriate dosage. A number of trials using various dosages and combinations of pituitary and human chorionic gonadotropin (HCG) have been made.

Aside from the HCG and crude extract of pituitary glands (either homoplastic or heteroplastic) salmon gonadotropin (SG100) has also been used to induce gonadal maturation and spawning.

Recently, researchers of SEAFDEC-AQD induced captive broodstock of sea bass to spawn using luteinising hormone-releasing hormone (LH-RH) analogues. The LH-RH analogues are administered in saline conditions of cholesterol pellet implants at 50–100 μg/fish weighing 4.7–7.0 kg. With this method they obtained about 300 000 to more than 1 000 000 eggs in one spawning with a fertilisation rate of from

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63.7 to 74.5% and hatching rate of from 3.5 to 43.9% (Nacario et al. 1984).

Attempts to spawn sea bass in captivity through environmental manipulation are being done at this laboratory (BAC). Experiments on the effect of photoperiod on gonadal maturation of sea bass broodstock where different day-lengths (10, 12 and 14 hours) are being tested are ongoing.

A total of eight tagged fish (4 males, 4 females) were stocked in three 12-m^3 concrete tanks indoors. Gonadal development and maturation were monitored by cannulation, histological examination or by use of gonadosomatic index (GSI). Daylight is simulated by use of fluorescent lamps installed in each experimental tank operated with automatic timer. An illumination rate constant of 27 482 μEin/cm^2/sec is being maintained in all tanks. This value corresponds to the mean illumination in nature for the months of March–August which coincides with the appearance of sea bass fry in the Philippines. The temperature of the tank water is maintained at 29.5 ± 1.0°C which is the average atmospheric temperature in nature, and salinity is maintained at 28–32‰. The fish are fed with chopped, bite-sized tilapia which has been washed in water (Oreta, D., pers. comm.).

Another environmental manipulation that will be tried at BAC is to induce the spawning of sea bass by creating an artificial environment in which the levels of salinity and temperature will be tested concurrently with varying photoperiod ratios. The specific hypothesis to be tested is that subjecting sexually mature sea bass to artificial monsoon conditions will stimulate reproduction. The end result of this research will be a technique for spawning sea bass in captivity by environmental manipulation which will aid efforts to develop another source of fry.

In another study, spawning of sea bass in earthern ponds is being attempted in order to simplify the method developed and employed by other research institutions. The objective is to develop simplified techniques of spawning that could be used easily by the industry. Sea bass ranging in size from 500 to 2000 g are being reared in earthen ponds and separated according to size. They are fed with chopped bite-size tilapia and fish rejects brought from fish markets. The fish are being fed to satiation. Physical, chemical and other biological factors are monitored regularly to be able to correct the conditions when they become undesirable for growth, gonadal development and maturation. Some of the parameters that are monitored very closely are temperature, pond depth, visiblity, dissolved oxygen content of water, ammonia and pH. Inasmuch as the fish in these ponds were collected from the wild and are of various sizes, their population in the ponds is inventoried occasionally and the fish are sorted according to size. As soon as they reach a minimum of 2.5 kg they are programmed for gonadal monitoring by any of the procedures mentioned above (cannulation, GSI or histological examination). As soon as gonadal maturity is detected the fish may be induced to spawn by administration of hormone or may be spawned naturally. Whenever possible, ripe males and females will be stripped and eggs will be fertilised by the dry method of artificial impregnation.

Synthetic hormones that have been used in Thailand such as Puberogen and Pregnyl will be tested. Other synthetic hormones that may be tried at BAC are clomiphene citrate, 17a-20B progesterone and deoxycorticosterone acetate (DOCA). These compounds are less expensive and require less handling than gonadotropins.

Research Needs

Despite the successful spawning of sea bass in captivity in the Philippines, studies on their biology as they adapt to the conditions existing in the country are still needed. Although sea bass larvae and fry have been collected from the wild, no definite spawning ground has been established in order to determine the various factors affecting spawning under natural conditions. For example, in Australia, it was established that the spawning grounds of sea bass are areas of high salinity (Moore 1982). Another important feature concerning sea bass spawning is its breeding cycle, wherein maturity is attained at 4 years as males, but later on at 6 years of age part of the stock change sex to provide females. This occurs in Australia and Papua New Guinea (Cogan 1984). In the Songkhla lakes in Thailand the spawning grounds are characterised by fast currents, high salinity (28–32‰) and deep water (Barlow 1981).

Some basic studies on sea bass that need to be pursued have therefore been identified. Simplification and refinement of techniques for spawning are needed in order for the industry to utilise them easily. These basic studies will contribute significantly to the full understanding of the biology of sea bass in the Philippines that will aid research in generating more information on sea bass spawning.

The following areas for research are therefore recommended: survey and identification of sea bass spawning grounds; biological studies on sea bass under natural and artificial conditions, e.g. environmental factors affecting broodstock, spawning behaviour, gonadal development and maturation, and breeding; and food and feeding habits of sea bass breeders under natural conditions; reproductive behaviour, hybridisation and genetics; development of appropriate techniques for sea bass broodstock rearing and maintenance; and refinement, modification and simplification of existing procedures.

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Releasing Hormones as an Effective Agent in the Induction of Spawning in Captivity of Sea Bass *(Lates calcarifer)*

Jonathan F. Nacario*

LUTEINISING-hormone-releasing hormone (LH-RH), a synthetic decapeptide, and its superactive analogues have been shown to induce gonadotropin secretion in teleosts. These compounds are therefore of potential use as ovulating or spawning agents in fish culture.

The following researchers have used LH-RH to advance the spawning period in a variety of fishes: LH-RH in pure form has been effective in female Chinese carp (Anon 1977a), female goldfish (Lam et al. 1976), female plaice and goby (Aida et al. 1978), female common carp (Sokolowska et al. 1978) and female coho salmon (Donaldson et al. 1981).

The superactive analogues have been reported effective in female grass carp (Anon 1977a), male goldfish (Peter 1980), female coho salmon (van der Kraak et al. 1983), and the female carp (Breton et al. 1983). These analogues, D-Ala^6 LH-RH A or D-Ser^6 LH-RH ethylamide have been administered in various vehicles like oil in female grass carp (Anon 1977b), propylene glycol in male common carp (Takashima et al. 1981), cholesterol pellet in male and female landlocked salmon (Crim et al. 1983) and in siganids and sea bass (Harvey and Nacario 1985).

This present study evaluated the effectiveness of the releasing hormones in various modes of administration in the induction of spawning of captive *Lates calcarifer*.

Materials and Methods

Sexually mature captive broodstocks (4–5 years old) of *L. calcarifer*, reared in canvas tanks at the SEAFDEC-AQD, Tigbauan, Iloilo, Philippines, were randomly selected during the spawning season (March–August 1984, 1985). Females weighing 4–11 kg and males 2–3 kg BW were checked for maturity by catheterisation.

Females with an average oocyte diameter of not less than 0.4 mm and males with freely flowing milt were chosen for hormone treatments. Spawning pairs/groups were placed in canvas tanks or ferrocement tanks with clean aerated sea water.

Hormone treatments were done as follows:

(a) 50 μg cholesterol pellet (Syntex Inc.) of 6-(D-2-napthylalanine) LH-RH were implanted intraperitioneally to both males and females under anaesthesia in phenoxyethanol (100 ppm). Treatments were 1–2 pellets per fish (50–100 μg/fish);

(b) 1 mg LRH-A (China) was dissolved in 10 ml Cortland's saline and injected IP to both males and females at the rate of 10 μg/kg BW; 2 injections 24 hours apart;

(c) 400–500 μg D-Ala^6-mammalian analogue was loaded in an osmotic pump and surgically implanted IP to females under anaesthesia in phenoxyethanol (100 ppm);

(d) Control groups remained untouched.

After every spawning, fertile eggs or hatched larvae were collected with fine mesh plankton nets and transferred to rearing tanks. Water in the spawning tanks was changed completely for the next spawning. Larvae were reared with rotifers from day 2 to 10 and subsequently with newly hatched *Artemia salina* nauplii up to day 25 and finely minced fish meat thereafter.

Results

LH-RH-treated females with 0.4-mm (and larger) oocytes spawned 2–4 days after hormone treatment while control fish did not. Results are shown in Tables 1–3. There appears to be a prolonged latency in the ovulatory response to LH-RH or LH-RHa; e.g. in goldfish, 1–4 days after the last injection. The same was observed in this study with *L. calcarifer,* although 2 days was more consistent. The reason is not clear since it is known that peak levels of blood gonadotropin are usually reached within 1 hour or less after treatment.

In this study, LH-RH administered in saline injections and cholesterol pellet implants gave comparable effectiveness in the induction of spawning *L. calcarifer* while the osmotic pump induced successive spawnings at 24-hour intervals (Table 3). The implantation methods had the advantage of minimising the cost of

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Table 1. LH-RH-a pellet implantation experiment with *L. calcarifer* in August 1984.

LH-RH-a treated fish	F_1	F_2
Body weight (kg)	6.0	4.75
Initial average egg diameter (mm)	0.46	0.46
Dose of LH-RH (μg)	100	50
(no. of pellets)	(2)	(1)
Date spawned	8/11	8/11
FR/HR (%)	74.51 / 43.92	56.36 / 22.03
Total eggs spawned	698 000	280 000

Table 2. LH-RH-a (Chinese analogue) injection experiment with *L. calcarifer*).

Date of Expt.	8/3	8/13	8/22
LH-RH-a treated fish	F_1	F_2	F_3
Body weight (kg)	5.50	4.75	11.00
Initial average egg diameter (mm)	0.487	0.455	0.522
Dose of LH-RH (μg)	10	10	10
(no. of injections)	(2)	(2)	(1)
Date spawned	8/5	8/15	8/23
FR/HR (%)	63.69 / 3.5		— / 5.13
Total eggs spawned	1 004 800	809 600	1 340 800

Table 3. LH-RH osmotic pump implantation.

Body weight (kg)	3	5
Initial AED (mm)	0.474	0.4925
Analogue used	D-Ala^6-M	D-Ala^6-M
Dose of analogue (μg)	400	400
Administration (IP)	OP continuous	OP continuous
Date spawned/(No. of eggs)	28/4/85 (1 800 000)	22/8/85 (3 092 000)
	30/4/85 (835 000)	23/8/85 (1 728 000)
	1/5/85 (627 000)	24/8/85 (1 080 000)
	2/5/85 (390 000)*	25/8/85 (20 000)
	3/5/85 (15 000)*	

* Spawned even without males

labour and eliminated the need for frequent handling of fish, a practical problem in fish easily stressed.

Further work is required to optimise LH-RH or LH-RH analogue treatments especially if the aim is to provide LH-RH stimulation for extended periods of time. The results of this experiment need further investigation and a systematic study of treatment dosages and treatment schedules would be of value.

The present study also demonstrated that the osmotic pump can be used effectively without rejection by the fish. There is some variation in the final development and shedding of eggs of *L. calcarifer* (Moore 1982). Some females probably shed all their eggs at once while others only a portion so that further development results in subsequent spawning. The latter case might be appropriately administered with LH-RH through the osmotic pump.

Other workers noted several points to consider, e.g. excessive dosages of LH-RH or analogue may be detrimental and responsiveness may vary seasonally with the reproductive cycle of the fish. While self suppression has been noted in goldfish after multiple injections of LH-RHa (Peter 1980), this negative effect was not observed in this study. Similarly, self potentiation could not be described since the time interval for injection and dose were the same. Variations in dosages and interval between injections are important considerations for such potentiation effects (Lin et al. 1982).

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Sea Bass *(Lates calcarifer)* Spawning in Tanks in Malaysia

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Tanjong Demong Marine Fish/Prawn Hatchery introduced the tank spawning method for sea bass in July 1985. We are the first and only marine fish hatchery in Malaysia to adopt this method since artificial spawning of sea bass was first discovered in 1971.

Previously, egg collection was carried out at the spawning ground from April to June between 1800 and 2030 hours on the first 4–5 days of early moon and full moon. However the success of this method depends on the weather conditions and luck (Ali and Fuad 1985).

The first successful natural spawning in a controlled environment was reported in 1975 (Tattanon and Maneewongsa 1982). There were two hatcheries, Songkhla and Satul in Thailand, which were successful in the spawning of sea bass in concrete tanks without hormone injection. The other hatcheries had to use hormone injection even though the broodstock was obtained from the same source. The reasons for this are still unknown, but may be related to the distance of the hatchery from the spawning ground, and the use of a net cage to keep the breeders prior to transferring them into the spawning tank (Maneewongsa 1982).

Spawning Tank

A 100 t round (10 m diam, 2 m deep) concrete tank was used for spawning. The inside layer was painted with dark-green epoxy paint to increase water resistance and for ease of cleaning.

The tank was equipped with an inlet and two outlets controlled by a gate valve which is connected to five 15-cm outlet holes, one in the centre and four at opposite sides around the tank bottom. There were also five aeration inlets connected to 4.5-kw rotary-type air blower.

Source of Broodstock

A few thousand selected sea bass fingerlings from Penang Fisheries Research Institute have been reared in net cages at Setiu Lagoon since early 1982. By June 1985 only 57 of them were still available, following a series of gradings, and losses due to general mortality and predation. Twenty-nine of the remaining broodstock were transferred into a spawning tank on 9 July 1985 when they were approximately 3.5 years old. They were selected on the basis of size, with 12 males and 16 females. The average body weight was 4.0 kg.

According to Rabanal and Soesanto (1982), the males are usually smaller with slender shape and narrower body depth. The females can be recognised by their big soft round belly and red-pink papilla extending out at their urogenital aperture. The reared broodstock were ready to start spawning at the end of their third year when they weighed about 3.5 kg, aged 2–4 years for male and 3–4 years for female (Tattanon and Maneewongsa 1982).

Some of the spawners were also caught from the nearby natural spawning ground in February–October particularly within a week of full moon either by hook and line or gillnet. Their body weight varies from 3.0 to 7.0 kg. Most of the fish weighing 4.0 kg or less are males and those 5.0 kg and above are females. A report from Penang Fisheries Research Institute said that all male fish measured had a body breadth less than 19 cm, while all female fish measured had a body breadth more than 22 cm, and they suggested that sex inversion (from male to female) could take place when the body breadth of the fish was around 19–22 cm. Moore (1979) indicated that there was a gradual increase in the female sex ratio with increase in total length and it was concluded that there was considerable variation in the size at which inversion takes place. There is also the possibility that some males do not undergo this inversion.

Broodstock Transportation

The broodstock from the net-cage in Setiu Lagoon were transported by road to a 100-t tank. The boats carrying the broodstock to the shore were unloaded during high tide. The spawners were removed from the net-cage into a 320-l fibreglass tank placed on the boat.

The spawners were again transferred from the boat into the same size fibreglass tank placed on a Land Rover. Each tank contained only two or three spawners and a continuous oxygen supply was provided at every stage of transportation.

Prior to transportation, the 100-t tank was filled with sea water to reduce stress to the spawners during release. The morning after transportation, water level

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was reduced to the 25-t level and 40 g of potassium permanganate ($KMnO_4$) was added for 3 hours then flushed with fresh sea water. This treatment was repeated for 3 days. This was followed by treatment with 1.5 l of formalin in 50 t of water for approximately 20 hours and also repeated two or three times on successive days. The treatment was continued with tetracycline at the rate of 20 mg/kg body weight until the fish totally recovered from their injuries sustained during transportation. The first feeding was started on the third day after release.

Broodstock Maintenance

Rearing fish in a confined environment demands not only highly skilled and knowledgeable management but also requires provision of adequate amounts of oxygen, removal of wastes and a quality diet. A number of undesirable situations can arise when waste feed and faecal material collects in rearing units.

Tank Cleaning And Water Quality Management

In order to maintain the above requirements, tank cleaning and flushing is necessary at least twice a week to remove waste material and seaweed from the tank bottom. In addition, rearing water must be changed every day, in the morning, and the water must be kept running for 2 hours before topping up. The salinity of sea water ranges from 25 to 34‰ and the temperature fluctuates from 24 to 37°C throughout the year.

A 4.5-kw air-blower was installed to provide an artificial aeration trough with five inlets of 2.5 cm diam PVC pipe. Another air-blower of the same type and capacity would be necessary for stand-by. A generator of 10 kw is also needed in case of power failure to run the air-blower as well as freezer and water pumps.

Feed and Feeding

Proper care of domestic broodstock is very important for assuring good production of eggs, fry and fingerlings. A suitable food for growth and maintenance in the amount needed is very important.

The spawners are fed with small fishes (a low grade fish for human consumption, but not an ordinary trash fish) at a rate of 2% body weight once daily. Round scad (*Decapterus ruselli*), fringescale sardine (*Sardinella fimbriata*), Indian mackerel (*Ratelliger kanagurta*), yellow goatfish (*Upeneus sulphureus*) and yellow-banded travally (*Selaroide leptolepos*) are among the small fishes without spines and with soft scales used for feeding.

The feed is washed and rinsed with the head portion and intestines intact. Feeding time is usually from 1100 to 1200 hours i.e. after completing water change or tank cleaning. The initial and final weights of feed was measured to know how much food was consumed each day because sea bass feed at different rates on different days. During spawning periods and on 1 or 2 days before the first spawning day, the spawners usually take less food and sometimes none. However, their feeding habits returned to normal immediately after the final day of their spawning period. Feeding also may be interrupted during courtship.

Fish typically lose 10–20% of their body weight during the spawning season. Much of this is probably caused by the release of eggs and sperms. The loss is more pronounced in females (Piper et al. 1982). Maybe for the same reason, the sea bass spawners at our laboratory gained only an average body weight of 0.5 kg within a year in the spawning tank.

Treatment Of Fish Diseases

Two general methods of treatment are usually employed: (1) drugs are incorporated into the feed of the fish, and (2) drugs are added directly to the water in the rearing unit. Tetracycline is one of the therapeutic agents incorporated into the feed at a rate of 20 mg/kg body weight, and is used to treat bacterial infections which appear to enter the fish through scratches or the digestive tract.

Formalin is effective against most external fish parasites, and probably the most widely used therapeutic agent in fish culture. It was used at 30 ppm for at least 20 hours and the treatment repeated two or three times on successive days. A bath treatment at 250 ppm for 1 hour is also applicable. However, at these concentrations, water temperature will affect the toxicity to fish of formalin which should be used only with caution. Aeration should always be provided during bath treatments to prevent low oxygen conditions from occurring. At the first sign of stress fresh sea water should be added to flush out the treatment.

Potassium permanganate is also used instead of formalin to control external protozoan parasites, monogeretic trematodes and external fungal and bacterial infections. It does not deplete the oxygen level and is a safe treatment in warm temperatures. Prior to the treatment, rearing water was reduced to the 25-t level and 40 g of $KMnO_4$ added (1.6 ppm). After 3 hours, the treatment is flushed out by adding new sea water. The treatment is repeated twice on successive days.

Because treatments are dangerous undertakings and to avoid the possibility of resistant strains of parasites and pathogens developing, they are only done when necessary, and especially after the spawning period when most of the spawners have scratches due to spawning activities. Outbreaks are usually prevented, however, through proper water management and tank maintenance.

Spawning and Egg Collection

Spawning takes place twice a month, i.e. a week before and a week after full moon. The spawning

period differs from 2 to 8 days or 4 days on average, and occurs year round. Egg production in the shorter period is always continuous, but egg production in the longer period is usually on alternate days.

Spawning activity always occurs between 1900–2300 hours. Egg collection was carried out in the morning at 0800–1000 hours or within 12 hours after spawning. There were two general methods of egg collection: net-scooping or net-hauling depending upon the numbers of eggs needed for our own use or for selling to local and foreign entrepreneurs. There are always approximately 5–10 million eggs produced during each spawning day with a hatching rate of more than 95%.

Hatching rate observations are considered to be one of the most important factors and should be carried out frequently to determine the effectiveness of egg fertilisation, since sex inversion commonly happens to the wild sea bass and is also believed to happen to domestic spawners.

Conclusion

The use of the tank spawning method for *L. calcarifer* either naturally or by hormone injection has a lot of advantages compared to the previous method of stripping the eggs at the natural spawning ground. It is not only less time-consuming but also the egg production in terms of number and period can be predicted, unaffected by environmental conditions or fluctuations, and eggs can be produced year round.

However, in the long term, certain measures should be taken to improve the broodstock quality. Inbreeding is one of the most important factors to consider if the source of spawners comes from hatchery fry. Problems that can arise after only one generation of brother-sister mating include reduced growth rate, lower survival, poor feed conversion and increased numbers of deformed fry. To avoid inbreeding, broodstocks should be selected from large, randomly mated populations.

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Developing Hatchery Techniques for Sea Bass *(Lates calcarifer)*: A Review

Niwes Ruangpanit*

LATES CALCARIFER, commonly called sea bass or barramundi, is an economically important fish in Thailand. It has been cultured for decades in Thailand in association with other coastal aquaculture systems for shrimp, mullet and milkfish (Ruangpanit et al. 1984).

Artificial propagation of sea bass was first achieved in Thailand in 1971 (Wongsomnuk and Manevonk 1973) by stripping the ripe and running spawners collected from natural spawning grounds. In 1975 they successfully induced the cultured broodstock to spawn in captivity. Since 1981, with the development of effective hatchery techniques, the problem of fry supply was largely overcome, thus allowing commercial culture of sea bass to expand rapidly along the coastal provinces of Thailand.

The Department of Fisheries of Thailand began to transfer the sea bass hatchery technology to private enterprise in 1980. There are about 10 private hatcheries that can produce from their own brood stock. In 1983–84, more than 50 private farms, both large- and small-scale, purchased the fertilised eggs and 2-week-old fry and nursed them to fingerling stage. The annual production of fry is more than 100 million. About 70% of fry and fingerling are exported to the international markets in Malaysia, Singapore, Hong Kong and Taiwan.

Hatcheries in Thailand

The size and capacity of sea bass hatcheries will depend on production targets and function of the hatchery. There are both large- and small-scale sea bass hatcheries in Thailand. The large hatcheries have complete systems, a spawning tank, larval rearing tank, and food organism tank. The small ones have only nursing tanks for nursing the larvae to fingerling (Table 1). Generally the ratio of rearing tanks, rotifer culture tanks, and green-water culture tanks is 1:2:4.

Sea Bass Spawning

There are two major techniques employed in mass production of sea bass fry in Thailand: artificial fertilisation and induced spawning.

Artificial Fertilisation

Spawners are caught in natural spawning grounds by gillnet near the mouth of the river or in saltwater lakes

Table 1. The following hatchery facilities are used in Thailand.

Stage	Facility	Stocking density	Unit volume (t)	Size, shape construction material
Adult	spawning tank	1 fish/5 ton	50–150	square 5 × 5 × 2 m, circular 10 m 2 m depth, concrete with aeration
Eggs	incubation tank	100–200 eggs/l	0.5–2	conical, circular, fibre glass, concrete
Larvae	larvae rearing tank	20–50 larvae/l	5–25	circular, rectangular concrete
Natural food	starter tanks		0.5–1	circular, fibre glass
Phytoplankton	algal culture tank		10–50	rectangular concrete
Zooplankton	rotifer culture tank		10–50	rectangular concrete

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like Songkhla Lake where water depth is about 10–15 m. Fishermen set the gillnet during spring tide at the full moon period until 5–6 days after the full moon. When the spawners are caught, they should be immediately checked for degree of maturity. If the female has ripe eggs and the male is in the running stage stripping is done in the field. Fertilised eggs can be achieved by mixing the sperm and eggs together. Leave the mixture in the container for about 5 min and then add clean sea water. The process of fertilisation takes 10 min, then the fertilised eggs are washed and sent for hatching. In cases where only the male is caught the milt is stripped and stored in a dry glass container in an icebox or refrigerator. The milt can maintain its viability about 1 week in cold storage (5–15°C) (Maneewongsa and Tattanon 1982a,b).

Induced Spawning

Two methods are used for inducing sea bass to spawn in captivity: hormonal injection and environmental manipulation. Both methods would induce the fish to spawn naturally in the tank.

HORMONE INJECTION

The brood sea bass are stocked in the prespawning tank for 1–2 months, then the females are inspected for ovarian maturity. Eggs are sucked orally by polyethylene cannula for measuring the diameter. When the eggs reach the tertiary yolk globule stage or have a diameter of 0.4–0.5 mm (Kungvankij 1984) the female is ready for hormone injection. For males only those with running milt are chosen. The hormones usually used to induce spawning in sea bass in Thailand are Puberogen and HCG.

ENVIRONMENTAL MANIPULATION

The techniques developed for stimulating the fish to spawn in captivity were based on field observations and analysis of natural phenomena that occur during spawning periods of sea bass. There are some factors that stimulate the fish to spawn in the tank:

Changing the water salinity Usually the brood fish are reared in cages where salinity fluctuated between 10 and 25‰. One month before the spawning season the brood fish are moved from the cages into the spawning tanks where the salinity is approximately 30–32‰. This is the same as the fish migration from its growing grounds to the spawning grounds.

Changing water in spawning tank Changing sea water by lowering the level and subsequently adding fresh sea water to the tank especially at the beginning of the new moon or full moon period, simulating the rising tide, will also stimulate the fish to spawn.

Changing the water temperature The fluctuation of seawater temperature in spawning tanks during exchange of sea water will also stimulate the fish to spawn.

Food Good quality and suitable amounts of food for spawners should be given. Feeding the spawners only about 1–2% of body weight should be adequate. Overfeeding can result in failure to spawn.

Egg Collection and Incubation

Natural spawning in controlled tanks takes place at the same time as natural spawning in open water, from the beginning of April to the end of September. The spawning in other periods must be induced by hormone injection. Spawning activity always occurs between 1900 and 2200 hours on the first to the sixth day of both the full and new moon. The fertilised eggs float at the surface whereas the unfertilised eggs sink to the bottom. The fertilised eggs range in size from 0.68 to 0.89 mm, but most were 0.74–0.80 mm (Maneewongsa and Watanabe 1984).

Eggs in spawning tanks can be collected and transferred to incubation tanks by either of the two following procedures: (1) The spawning tanks are supplied with continuous flow of sea water. Sea water should start to flow after the fish have spawned. The overflowing water carries the eggs into a small tank containing a plankton net (200 μ mesh). Eggs are collected and transferred to incubation tanks the following morning. (2) The eggs are collected from spawning tanks using a fine mesh (200μ) seine net the morning after spawning.

Eggs are collected with fine mesh net and placed in incubation tanks at 100–200 eggs/l passing through 1 mm mesh screen in order to remove floating algae and other debris that have adhered to the eggs.

Normally fertilised eggs will float while the unfertilised eggs settle to the bottom of the container. Unfertilised eggs are later removed by siphoning. The eggs will hatch out at about 12–15 hours at 29–31°C and 17–18 hours at 26–28°C after spawning. Hatching rate will depend on the water salinity. The optimal salinity for hatching appears to be between 20 and 30‰ (see Sujin Maneewong, these Proceedings).

However, the hatching rate of sea bass eggs by environmental and hormonal manipulation ranges between 40 and 85 and 0.1 and 85% respectively (Kungvankij et al. 1984).

Larval Rearing

The rearing tanks commonly used in Thailand are made of concrete. There are both rectangular and circular shapes located both outdoors and indoors. Volume ranges from 5 to 25 t. The process of larval rearing is divided into two steps: primary rearing extends from hatching to a larval size of 4–6 mm in total length or 10–15 days after hatching; the second step, secondary rearing, covers the period up to 6–15 mm size or 16–35 days after hatching.

Primary Rearing

The newly hatched larvae are carefully collected in the morning by siphoning or scooping them with a beaker and immediately transferring them to larval rearing tanks where filtered sea water and mild aeration are provided. The stocking density for newly hatched larvae in rearing tanks is 50–100 larvae/l. The bottom of the larval rearing tanks should be cleaned every day after stocking.

Good quality sea water (30-31‰ is required for larval rearing. Every morning 30–50% of sea water is changed and replaced. If possible, a running water system should be used in the rearing tank for 2 days before feeding. Water temperature is also important and should be in the range 28–30°C to stimulate the fast growth of larvae.

Feeding with rotifer *Brachionus plicatilis* was commenced on the second day after hatching corresponding with the completion of mouth opening which was generally observed in the afternoon of the second day. Rotifer should be given in adequate amounts up to age 15 days. A rotifer density of 10–20/ml was required for one rearing tank. The amount of rotifer used to feed the sea bass larvae (age 2–9 days) per day was determined (Table 2; Pechmanee et al. 1984).

Table 3. The average growth (T.L. mm) of sea bass larvae reared at different densities. Source: Maneewongsa and Ruangpanit (1984).

Age	No. larvae/l			
(days)	50	80	110	140
1	1.24	1.24	1.24	1.24
5	2.99	2.91	2.71	2.93
8	3.31	3.24	3.16	3.29
11	4.58	3.93	4.10	3.91
13	5.16	4.51	4.27	4.19

During brine shrimp feeding, approximately 50% of water is changed while most changing is made during the trash fish feeding period. The management of sea bass nursing is shown in Sujin (these Proceedings). The survival and growth of larvae are 77.7, 87.7, and 90% at stocking densities of 10, 20 and 30/l, and 12–16 mm respectively. The best growth was attained by larvae reared at 10 individuals/l. Most of them can be fed with fish meat when they reach 25–30 days while most in the other two groups in the higher density are still fed brine shrimp nauplii (Maneewongsa and Ruangpanit 1984b).

Table 2. The amount of rotifer fed to sea bass larvae/day. Source: Pechmanee and Ruangpanit (1984).

Rep. No.	Age of larvae *(days)* 2	3	4	5	6	7	8	9	Remarks
1	369	164	410	820	820	1066	984	984	Stocking 40
2	278	556	648	648	1204	1019	1019	833	larvae/l
3	369	553	560	560	876	1107	1245	1199	in 30–l
4	478	318	398	398	955	955	1115	1035	containers

Green water either from *Tetraselmis* or *Chlorella* sp. should be added daily to maintain a density 8–10 $\times$ 10^3 or 3–4 $\times$ 10^4/ml respectively. The algae serve a dual purpose: as a direct food to rotifer and a water conditioner in the rearing tank. Brine shrimp (*Artemia* sp.) nauplii were used to feed larvae together with rotifer from age 8 days. The larvae were reared in these tanks until 15 days old. The survival rate was between 60 and 85% at densities of between 50 and 140/l. The growth rate is 4.19–5.16 mm (Maneewongsa and Ruangpanit 1984a, Table 3). Then they were distributed to nurse in the nursing tank.

Secondary Rearing

When the fish larvae reached 15 days they were distributed to nurse in another nursing tank. The larval density is then reduced to about 10–30 larvae/l. The diet is switched to brine shrimp (*Artemia* sp.) nauplii. After the fry reach 11–15 mm (about 25–30 days old) ground fish meat can then be used as feed. Subadult and adult brine shrimp are also used to feed the fry.

Larval Feeds

The culture of microorganisms as food for larvae of fish is very important. The success of the production of fish fry depends on a constant supply of food.

Phytoplankton Culture

Algal species used in sea bass hatcheries in Thailand are *Chlorella* sp. and *Tetraselmis* sp. The first stage of the phytoplankton culture is conducted in the algal room, except for large-scale culture which is done outdoors. It is necessary to maintain pure stocks of algae throughout the year.

Mass production of phytoplankton started at a 1–l scale. The scale of culture was then gradually increased to a volume ratio of 1:10. The average culture cycle in unicellular algal mass production is 3–5 days. Cell density is 1–2 million cells/ml for *Chlorella* sp. and 80 000–120 000/ml for *Tetraselmis* sp. (Maneewongsa et al. 1984). The measurement of cell density by means of a blood cell counter is used only at the first stage culture. For the estimation of cell density

in the large-scale culture, the measurement of transparency of green water was employed by using a white disc 15 cm in diameter. The culture of *Tetraselmis* sp. in Thailand was quite successful compared with *Chlorella* sp. which was usually contaminated with a blue-green alga (Fox 1983).

Tetraselmis sp. can be cultured in natural sea water between 15 and 36‰ and grown at temperatures between 15 and 33°C under natural light conditions. Because the temperature of the outdoor tank for culturing phytoplankton was between 26 and 33°C, *Tetraselmis* was suitable for culturing for feeding rotifer in Thailand. The culture media for these algae are as follows: ammonium sulfate, 100 g/t; superphosphate, 15 g/t; urea, 5 g/t.

Rotifer Culture

There are many species belonging to Rotiferae, but the most suitable for mass culture appears to be *Brachionus plicatilis*. It is an important and indispensable food for marine finfish larvae. It is rich in nutrients and small in size for the larvae to consume (Anderson and Smith 1983).

Rotifer are usually reared in concrete or fibreglass tanks. The size of the culture tank ranges from 1 to 50 t. The tanks are initially filled with *Chlorella* sp. or *Tetraselmis* sp. cultured at a density of 10×10^6 and 10×10^4 cells/ml respectively. Rotifer was added at a density 10–20/ml, reaching 80–100/ml for 5 days. It was then ready for harvesting by siphoning the water from the rotifer culture tanks through 63-μ mesh bags, leaving half of the original column to serve as a starter for the next batch. Then phytoplankton (100 000 cells/ml) were added to the rotifer culture tank to the same level in order to grow the next batch of rotifer. Dry baker's yeast was added as a supplementary food at the rate of 0.5 g/million rotifer when water in the rotifer culture tanks became clear. Each rotifer culture tank was used for culturing for 7–10 days, then cleaned and reused (Pechmanee and Ruangpanit 1984).

Grading Techniques

Grading is essential to minimise the drop in the number of larvae due to cannibalism. The production of fish will be greatly affected if fry of different sizes are stocked together; cannibalism will occur after they are 2 weeks old. The material usually used for grading consists of plastic containers punched at the bottom with holes of 2, 3.5, 5, 6 and 7 mm diam. Fish are placed in the plastic containers which are floated in the newly prepared larval rearing tank. The small fish can pass through the hole to the new tank. The remaining fish in the vessel are transferred into another tank and likewise graded with the use of a bigger hole or mesh plastic container. This procedure sorts out fish to several sizes and simplifies management. The frequency of grading depends on the variation that is observed daily in the size of the fish, but usually every 5–7 days.

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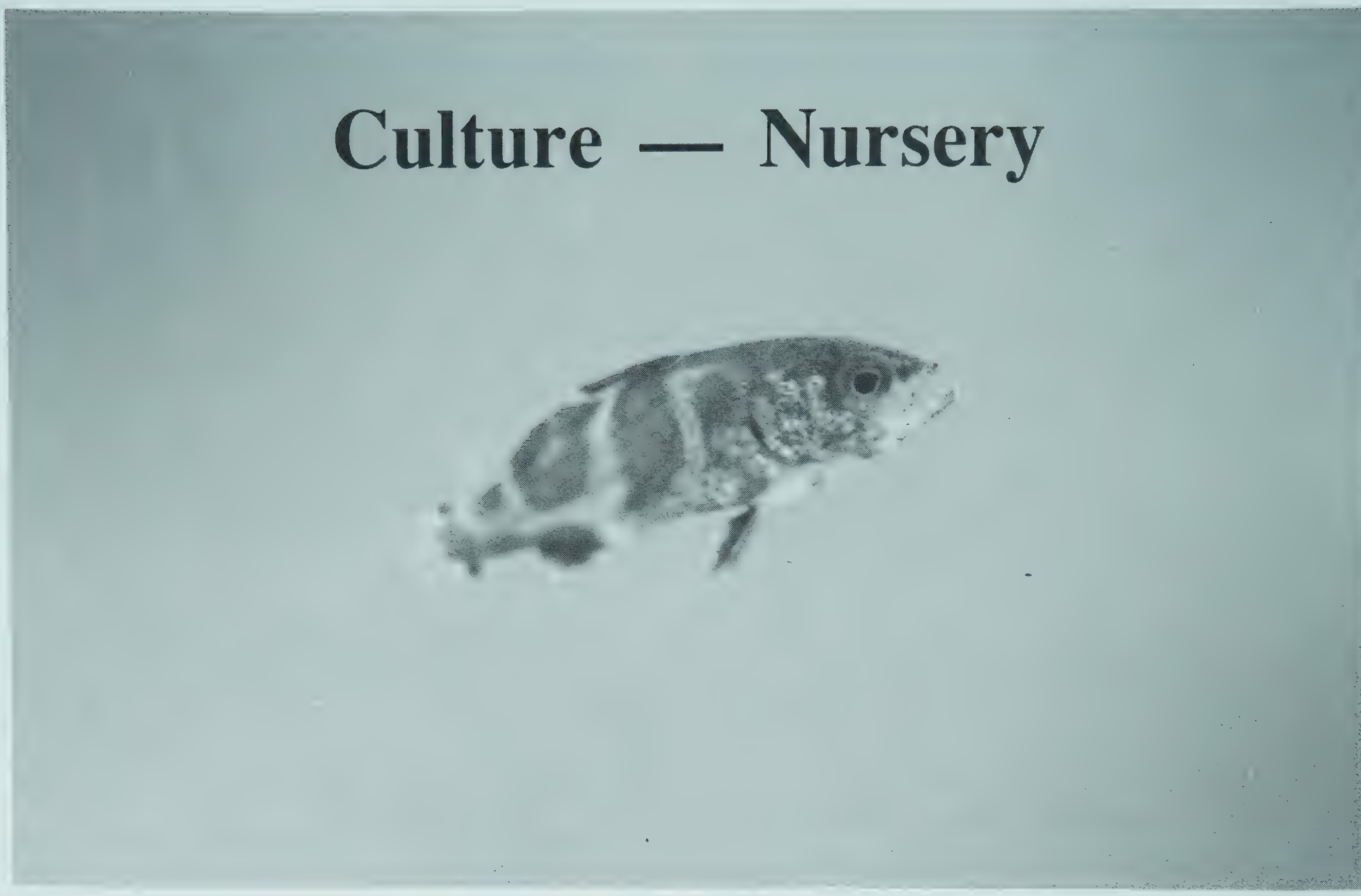
Culture — Nursery



Research on the Nursery Stages of Sea Bass *(Lates calcarifer)* in Thailand

Sujin Maneewong*

SINCE 1976, research in Thailand on sea bass *(Lates calcarifer)* spawning and nursery stages covered many topics, but most of the work concerned the following: *Broodstock culture:* source, collection and selection of brood fish; food and feeding was also studied; *Environmental effects on spawning behaviour:* spawning of sea bass under controlled environments, and effect of hormone injections to stimulate spawning; *Nursery stage of larvae and juveniles:* food and feeding, stocking density, growth and nutrition; *Pathology:* disease, infection, kinds of disease, prevention and cure of diseases; *Effect of environment:* salinity, NH_3, NO_2, which affect survival rate and growth of sea bass.

Nursery Stage

The nursery stage is one of the most important steps in seed propagation. Many factors must be considered at this stage to avoid high mortalities and to maintain high production. The factors are: water quality, food and feeding schedule, stocking density, grading of fry, and disease.

Water Quality

Turbidity of seawater should be as low as possible, the water filtered to remove dirt and organisms that might be harmful to larvae and fry. Salinity should be 25–30‰ for rearing larvae, fry and food organism culture. For the first 15 days, salinity is maintained at about 20–28‰, then reduced to between 10 and 20‰. In fact, sea bass larvae can tolerate low-salinity or fresh water, but for growth larvae and fry require estuarine water.

Water exchange for the first 15 days is about 10–50% daily. From 15 to 25 days old, the water exchange rate should be higher than 50% and at least 80% when feeding with fish meal begins. Dirt and waste deposited on the bottom of the rearing tank is siphoned off every few days.

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** Larvae: from hatch-out to complete metamorphosis (0–15 days TL 4–5 mm): Fry: after complete metamorphosis to fingerling size or juvenile.

Food and Feeding Schedule

Food is the most important factor affecting growth and survival of sea bass larvae and fry.** Many kinds of food are fed to the larvae and fry depending on age or size. Zooplankton is the most suitable food for larvae at the early stage of rearing. The feeding schedule is shown in Fig. 1.

ROTIFER

The mouths of the larvae open when they are 2 days old (on the third day after hatch-out); feeding of rotifer to the larvae should be started. Rotifers are added to the rearing tank daily (5–15/ml of water) when the larvae are 3–7 days old. When the larvae are 8–15 days old the density of rotifer in the rearing tank should be increased to 15–20/ml. Some amount of green water (*Chlorella, Tetraselmis*) is also added to the tank (about 5% of water volume). The amount of rotifer added to the rearing tank each day should be adjusted to maintain sufficient feed for the larvae.

An experiment was done using 30-t tanks to compare effectiveness of live rotifer, frozen rotifer, and boiled egg yolk as food for early stages of sea bass larvae (Pechmanee et al. 1984). Frozen rotifer and boiled egg yolk were inferior as food for sea bass larvae.

Maneewong et al. (1984) conducted an experiment in large tanks (30 t) using live rotifer, frozen rotifer, egg yolk and egg + instant milk. The result was that live rotifer is the most suitable food for 3–12-day-old larvae. However, it may be possible to use frozen rotifer which was associated with a higher survival rate (Table 1) than boiled egg yolk and mixture of egg and instant milk, as a supplemental food for 2 or 3 days when there is a shortage of live rotifer.

BRINE SHRIMP NAUPLIUS

Feeding of brine shrimp nauplii to sea bass larvae is started at 8–10 days old. The density of nauplii in the rearing tank is 1–1.5/ml initially and is increased gradually to 4–5/ml and 6–7/ml when the fry are 15 and 20 days old. Amount of brine shrimp nauplii should be controlled every day, by watching the number of nauplii remaining in the rearing tank uneaten and condition of the fry. If the fry are

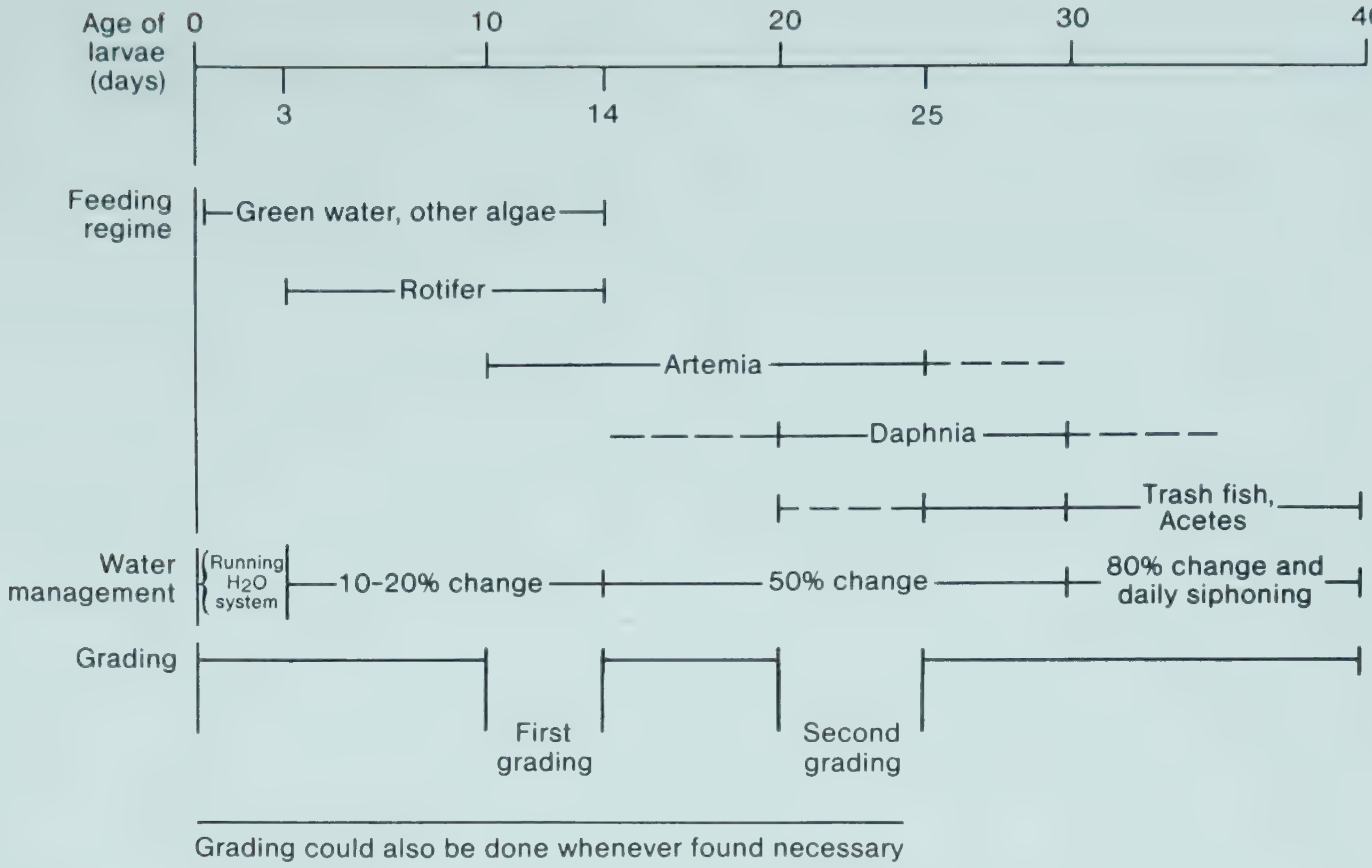

Fig. 1. Management method for sea bass nursery tank for the initial 40-day period.

Table 1. Survival rate of sea bass larvae fed with different kinds of food.

Tank	Food	Stocking No.	Surviving No.	Survival rate (%)
1	Live rotifer	1 000000	326000	32.6
2	Live rotifer	500000	204000	40.8
3	Frozen rotifer	546000	10000	1.8
4	Frozen rotifer	510000	10000	2.0
5	Egg yolk	490000	10000	1.9
6	Egg yolk	520000	7500	1.4
7	Egg + instant milk	492000	8400	1.7
8	Egg + instant milk	485000	5000	1.0

swimming fast in the tank, they require more food. Normally brine shrimp are fed to the fry until 20–25 days old.

An experiment conducted in 30-l containers showed that number of nauplii eaten by one larva 11–17 days old was related to the age of the fry; 15-day-old fry consume as many as 300 nauplii each/day.

Maneewong et al. (1981) conducted an experiment using rotifer, rotifer mixed with brine shrimp and rotifer mixed with moina fed to 3–15-day-old larvae. The results showed that the survival rates were 40.4, 47.5 and 19.1% respectively. The survival rate of larvae fed with rotifer + moina was very low because the rotifer was stopped when the larvae were 8 days old. They were then fed with moina until they were 15 days old, but larvae were too small to eat the moina. However, for the surviving larvae fed with rotifer up to 15 days old, then with moina until 25 days old, the survival rate of the fry was about 91%. To avoid using very expensive brine shrimp, the fry may be fed rotifer feed up to 15–20 days old and with moina after 15 days old (TL = 4–5 mm).

MOINA, DAPHNIA OR COPEPODS

At around 18–25 days old, water flea and copepods were used as a supplemental food to minimise costs.

It is recommended that sea bass fry be fed with zooplankton larger in size and richer in nutrition than brine shrimp nauplius, such as water flea and copepods whenever these zooplankton are available in sufficient quantity.

The freshwater fleas (*Daphnia* and *Moina*) are used at the National Institute of Coastal Aquaculture (NICA). They die and decay in the rearing tanks if they are not eaten by the fry in a short period. To avoid pollution of water in the rearing tanks caused by uneaten water fleas, feeding is done by gradual feeding or siphoning the water flea, kept in a bucket of fresh water, drop by drop into the rearing tank. The water in the bucket should be aerated well to distribute the water flea evenly. Actually the freshwater flea is fed to the fry until the fry are about 1.5 cm in total length (30–40 days), when they can eat fish meat.

FISH MEAT

The food of sea bass fry is changed gradually from zooplankton to minced fish meat at about 25 days old (about 10 mm in total length). Small and clean particles of fish meat are prepared by using minced fish meat passed through the screen (mesh is about 3–4 mm) for size selection. The particles of fish meat are fed to the fry in the same manner as the feeding of water flea. Amount of fish meat given to the fry in a day is about 10–15% of body weight. The body weight of 25-day-old sea bass fry is about 0.15 g. The amount of fish meat should be controlled depending on observations of fish condition and water quality. Feedings are done twice a day, in the morning and in

the afternoon, and brine shrimp or water flea is given to the fry as supplemental food after feeding with fish meat in the afternoon.

Actually the fry should be reared up to 2–2.5 cm in total length before being transferred to cage or pond for further rearing to suitable size for culture (5–7.5 cm in total length).

Stocking Density

Stocking rate of sea bass larvae and fry at NICA hatchery depends on age and size of larvae or fry as shown in Table 2. From 1 to 15 days old no grading takes place, therefore there is no change in the density of the fry. The density, however, will decrease naturally to 30–50% of initial stocking density with mortality of the fry. After 15 days the stocking density will be decreased to avoid cannibalism and to allow normal growth of the fry.

Table 2. Normal stocking rate for sea bass seed propagation in 30 m^3 tank at NICA hatchery under normal conditions.

Age (days)	Total length (*mm*)	Approximate no. larvae or fry/1 m^3	Survival rate (%)
1–15	1.5–5	30000–40000	30–50
15–20	5–8	2000– 4000	60–80
20–25	8–10	1000– 2000	70–80
25–30	10–13	1000– 1500	80–90
30–45	13–30	500– 1000	80–100

Maneewong et al. (1983) conducted an experiment on stocking density of sea bass fry from 1–12 days old at densities of 50, 80, 110, and 140/l in 500-l tanks filled with 400 l of sea water. From the experiment it can be said that the initial maximum stocking density of 1–12-day-old larvae should be 50 larvae/l. If the stocking density is higher than that, survival and growth rates of fry will drop (Table 3).

An experiment on stocking density of sea bass fry (10, 20 and 30 fry/l) was conducted by Maneewong et al. (1983) in 500-l tanks to determine the highest possible density to rear healthy fry aged 13–29 days (Table 4). The lowest survival rate at the lowest density could be attributable to cannibalism among fry. Fry reared at higher densities were too small and weak to eat each other, which might result in a higher survival rate. The maximum density at which the fry can grow normally to 13–29 days falls between 10 and 20 fry/l.

Grading of Fry

Cannibalistic behaviour of sea bass fry can be observed after the fry completes metamorphosis, when they are about 15 days old (about 5 mm TL). To maintain a uniform size and minimise the mortality of the fry, the grading of fry to size groups at regular and frequent intervals must be done. Actually, after the first size grading at around 12–15 days old, size grading is done every 3–5 days. The first grading is done by a stick net, made of plastic mosquito net (2 mm mesh size). Smaller fish pass through the net and are left in the tank, while those larger size caught by the net are transferred to a separate tank. From the second grading, grading is done by using plastic buckets with pores through which fry of a certain size can pass. After 15 days, plastic buckets with gradually larger pore size are used for grading. Pore size of each bucket is 3.2, 4.8, 6.4, 9.5 and 12.7 mm, respectively. Usually grading is done every 3–5 days or whenever it is found that the fish size is not uniform.

Table 3. Number of surviving fry.

Tank no.	Stocking no.	Surviving no.
50 fry/l		
1	22500	19000
2	22500	20000
3	22500	19000
80 fry/l		
1	36500	25000
2	36500	26000
3	36500	28000
110 fry/l		
1	49500	28000
2	49500	26000
3	49500	36000
140 fry/l		
1	63000	38000
2	63000	47000
3	63000	44000

Table 4. Number of surviving fry.

Tank	Stocking no.	Surviving no.
10 fry/l		
1	5000	3250
2	5000	4400
3	5000	4000
20 fry/l		
1	10000	8650
2	10000	8900
3	10000	8750
30 fry/l		
1	15000	13100
2	15000	14070
3	15000	13350

Disease

Many diseases have been identified in cultured sea bass in southern Thailand such as gill fluke, white

spot, trichodiniasis, hirudinea, etc. Among these diseases white spot is most commonly observed during hatchery operations. Diagnosis and treatment of fish diseases at fry stage have not been well established, especially for subtropical and tropical species. The most important preventative measure for disease is to grow strong fry, which can withstand pathogenic agents, through proper control of water quality, provision of clean rearing tanks, provision of fresh, high-quality feed in proper quantity, and appropriate stocking density of fry.

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Effect of Stocking Density on Survival of Sea Bass *(Lates calcarifer)* Larvae

Niwat Suteemechaikul* and Saeree Petchrid**

DURING the past decade, interest in culture of sea bass *(Lates calcarifer)* has increased in Thailand. This interest stems from a need for a supply of sea bass through culture to replace production through natural fishing, which has decreased dramatically in recent years. Because sea bass can tolerate a wide range of salinity, from fresh to marine, and production of fry through artificial propagation has been done successfully, sea bass culture has been expanded intensively throughout the coastal areas of Thailand (Tiensongrusmee 1974; Department of Fisheries 1983).

With the expansion of intensive culture, there is a marked increase in demand for sea bass fry for stocking. As a result, more than 10 hatcheries were set up to produce fry to supply to the fish farmers.

Although fry can be produced, problems still remain. The most serious problems are due to cannibalism and high mortality during transitional stage, when larvae refuse to accept minced trash fish which was introduced instead of brine shrimp (*Artemia salina*) larvae. When these problems occur starvation and lowering of survival rate will result (Brown 1957; Weatherley 1966, 1976).

However, it was shown that cannibalism is directly related to population density. A larger fish is found to be a more effective competitor than a smaller one. Hence, growth and survival rate of fish can be improved when proper stocking density is used (Backiel and Le Cren 1967; Teng and Chua 1978).

The present study was intended to investigate the optimum stocking density for nursing of sea bass larvae during the stage when minced trash fish was first introduced to the larvae.

Materials and Methods

Test Fish and Condition

Sea bass larvae used in this study were reared from first hatching to 25 days after hatching at the hatchery of Satun Brackishwater Fisheries Station. On day 25 after hatching, they were transferred into the laboratory to begin the experiment.

Nine 15-l glass aquariums were set up in the laboratory. Each aquarium contained 15 l of sea water, which has the following qualities: temperature 25.0–28°C, salinity 30–32‰, pH 7.2–7.7, dissolved oxygen content 5.5–10.1 mg/l, nitrite 0.002–0.200 mg N/l, ammonia 0.00–0.09 mg N/l and phosphate 0.002–0.23 mg PO_4/l. Three sides (left, right and rear) of all aquariums were covered with black paper to prevent intense light and social effects.

Food and Feeding

Minced fresh sardine was fed to the larvae in each aquarium twice a day (0900–1000 and 1700–1800 hours). Larvae were fed to satiation in each feeding. About 15 min after feeding finished, uneaten food was siphoned out. Then half the volume of water in each aquarium was filtered out through a 1-mm mesh filter and refilled with fresh filtered sea water.

Experimental Design

Aquariums were divided into three groups of three aquariums each. Then 25-day-old sea bass larvae averaging 1.67 ± 0.22 cm TL and 0.0916 ± 0.0105 g, were put into each group of aquariums at three stocking densities (total larvae/aquarium in parentheses): 10(150), 15(225), and 20(300) larvae/l of water, respectively.

This experiment lasted 25 days. Survival rate, individual total length and weight were measured and averaged. Analysis of variance was used to test the effect of stocking density on the various growth parameters and survival rates ($P \geqslant 0.05$) and Duncan's Multiple Range Test was employed to compare the significance of the means of the growth parameters among the tested stocking densities ($P \geqslant 0.05$).

Results

At the end of this experiment, average survival rates of the sea bass larvae stocked at the densities of 10, 15 and 20 larvae/l were 99.9, 99.3 and 98.1%, respectively. However, the average survival rates for the three

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stocking densities were not significantly different.

Growth Parameters

After 25 days nursing at the stocking densities of 10, 15 and 20 larvae/l, the average weights of the tested larvae were 0.3169 ± 0.1311, 0.2465 ± 0.1013 and 0.2662 ± 0.1182 g, respectively, and average total lengths were 2.93 ± 0.46, 2.69 ± 0.44 and 2.43 ± 0.32 cm, respectively. The differences amongst the average weights and amongst the average total lengths of the tested stocking densities were small and statistically not significant.

Discussion

Although there is no statistical significance between the growth and survival rates of sea bass larvae stocked at each density, the average growth and survival rates of larvae stocked at the lower densities were better than the higher ones. The results may be the effects of high stocking density on fish: reduction of growth rate, increasing food conversion ratio and lower survival rate (Powell 1972).

During this experiment, competition for food occurred. Weatherley (1966) stated that the intensity of competition for food is directly related to the population density. Within a population density, a larger fish eats more food than a smaller one and is a more effective competitor by a factor related to its size. Feeding of a few larger fish in a crowded situation may prevent others from feeding adequately.

The highest stocking density (20 larvae/l of water) tested in this experiment is recommended. The higher the stocking density of larvae, the higher the economic return. We also found that the survival rate is reduced in deeper nursing tanks. Hence, the depth of the nursing tank for sea bass larvae should be less than 0.5 m. At this depth, cleaning of the tank is easier and water quality can be maintained.

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Sea Bass *(Lates calcarifer)* Larvae and Fry Production in Malaysia

Ali bin Awang*

Sea bass larvae and fry were first successfully bred in Songkhla, Thailand, in the mid 1970s (Brohmanoda 1982). Due to the close proximity of southern Thailand to the northern states of Peninsular Malaysia, a considerable amount of sea bass fry had been imported to Malaysia from Songkhla and other parts of southern Thailand. Since then, the easy availability of fry from Thailand has encouraged the popularity of the culture of this species especially in floating net cages in our coastal waters.

The first success in the larvae and fry production of sea bass in Malaysia was carried out in the Fisheries Research Institute, Glugor, Penang, in 1982. This success further stimulated the growth and popularity of sea bass culture in Malaysia. Production of sea bass has increased to an estimated 400 t/year and is expected to increase to 4000 by the year 2000 (Ubaidillah 1985).

Materials and Methods

Spawners

Spawners were caught from coastal waters near Telok Air Tawar, Penang, during the breeding season (between late March to July), which coincided with the rainy season.

They were caught with a bottom drift net with mesh size 175 mm. Fishing was usually carried out on 4–5 consecutive days during the new- and full-moon phases between 2000 and 2200 hours.

The mature male and female fish were stripped and the eggs were fertilised on the fishing vessel and then transferred to the hatchery in plastic bags.

Culture Facilities

Conical 1.8-m diam fibreglass tanks with a capacity of 2 m^3 were used for incubation and hatching as well as for rearing the early larval stages.

For the later larval stages, larger tanks such as circular 3.5-m diam fibreglass tanks with a capacity of 9 m^3 and rectangular ($8 \times 2 \times 1$ m) cement tanks with a 16 m^3 capacity were used.

Rotifer (*Brachionus plicatilis*) used as the first food for the fish larvae was cultured in 16 m^3 rectangular cement tanks.

For culturing *Chlorella* sp. and *Platymonas* sp., various sizes and types of containers were used from laboratory stage to the final stage in the hatchery. In the laboratory the cultures were first started in a series of 2-l round-bottom flasks. Gradually, the cultures were enlarged in a series of 20-l glass aquariums and then in 200-l glass aquariums. The cultures were further enlarged in the hatchery in a series of 2 m^3 rectangular ($3.0 \times 1 \times 0.7$ m) fibreglass tanks and finally in 16 m^3 cement tanks.

Live Food Culture

CHLORELLA AND *PLATYMONAS*

In the culture of these microalgae in the laboratory, the sea water was boiled and cooled and the 2-l flasks were autoclaved in the oven before use. As for the nutrient, the following stock solutions of 1-l each were prepared: potassium nitrate 100 g, sodium biphosphate 10 g, sodium EDTA complex 3 g. One mililitre of each stock solution was added to 1 l microalgae culture.

In the mass culture of these microalgae the sea water was sterilised overnight with 5 g hypochlorite/m^3 of water with strong aeration. Before it was used the next day, the chlorine content was checked. If chlorine was present, 9 g of sodium thiosulfate/m^3 of water was added. As the nutrient for these cultures, the following commercial grade chemicals were added to each cubic metre of culture water: ammonium sulfate 100 g, calcium superphosphate 10 g, urea 10 g.

ROTIFER

In the culture of *Brachionus*, a partial-harvest system was used with slight modification (Watanabe 1982). Initially, the culture tank was one-third filled with microalgae and then inoculated with *Brachionus*. After 4–7 days, depending on the density of inoculation, the microalgae was consumed and *Brachionus* population multiplied. Additional microalgae was pumped to the full capacity of the tank. When the microalgae was consumed and the *Brachionus* population had increased, a certain proportion of the culture was siphoned through 60-μ mesh size screen to collect the *Brachionus* for feeding, depending on the demand.

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The culture was continued by pumping new microalgae to the tank. The procedure was repeated until the tank was laden with bottom waste when the culture was stopped and the tank was washed and disinfected with hypochlorite.

Often, the microalgae collapsed. Therefore, it was necessary to use baker's yeast to supplement the microalgae. The amount used was 1 g yeast/1 million *Brachionus*.

Larviculture

INCUBATION AND HATCHING

The eggs were washed with filtered sea water and stocked in conical fibreglass tanks which were three-quarters filled with new filtered sea water. Normally the egg density was in the region of 60 000 to 100 000 eggs/1000 l of sea water. The aeration was moderate.

Hatching usually occurred at about noon the next day (i.e. about 12–19 hours after the fertilisation of the eggs). The aeration in the tank was then stopped for about 30 min after the majority of the eggs had hatched in the afternoon. This procedure was taken to enable the unhatched eggs and other detritus to settle and later to be siphoned out.

REFEEDING

The water was changed by siphoning the water through an appropriate screen box, and new water was added simultaneously. The new hatchlings were still fragile and their mobility was limited; therefore the above process was done carefully so as not to injure the larvae. The larvae population was estimated by taking samples in a 500-ml beaker.

On the second day of culture, a small amount of *Brachionus* and microalgae was added to the rearing tank to ensure that food was immediately available to the larvae when they started to feed on the third day.

BRACHIONUS

The fish larvae were given only *Brachionus* from day 3 to day 10, twice a day: once in the morning and once in the afternoon. However, the presence of *Brachionus* in the larval tank and the satiated stage of the larvae were constantly checked. If the stomachs of the larvae were empty and the majority of *Brachionus* were consumed, more *Brachionus* was added to the larval tank. In the afternoon a greater amount of *Brachionus* was added to the larviculture tank. The next morning, before changing water, the same checking procedure was performed.

Cleaning and siphoning the dirt were done whenever necessary. As the culture progressed, more frequent cleaning and siphoning were done due to accumulating wastes and growth of periphyton on the sides and bottom of the tank. The culture water was completely renewed every day.

On the eighth day of culture, the larvae were transferred either to the 9 m^3 circular fibreglass tanks or the 16 m^3 rectangular cement tanks.

ARTEMIA NAUPLII

The *Artemia* nauplii were fed to the larvae on the 10th day till the 30th day of the culture. On the first 5 days of this stage small amounts of *Artemia* nauplii together with *Brachionus* were given to the larvae in order to let the larvae get used to the new type of food. This period of adaptation ran with little problem as the larger larvae tended to prey on much larger food particles.

The amount of *Artemia* cysts used for feeding about 300 000 larvae was 4 kg/day (i.e. for one cycle of larviculture), where the *Artemia* nauplii feeding stage took about 20 days, about 80 kg of *Artemia* cysts was used.

The feeding regime and constant checking procedure were similar during the rotifer feeding stage. More attention was paid to the cleanliness of the larviculture tank at this stage during which the larvae were feeding actively. The water was completely changed every morning and the procedure was similar as in the earlier stage.

MINCED FISH OR PRAWN FLESH

This stage usually began on day 20 and initially the minced flesh was given together with *Artemia* nauplii. The minced flesh was given sparingly and a few times a day to train the larvae to accept the 'inert' food.

Since the minced flesh easily fouled the water, a complete water change had to be carried out more frequently. The general cleanliness of the tank had to be attended to more often and all the uneaten food had to be siphoned out.

Grading

The sea bass larval population showed a disparity in their growth rate. A few percent of its population showed very fast growth rate and developed as giants. These giants showed highly cannibalistic behaviour and preyed on smaller individuals. Therefore to reduce this effect, grading of larvae was necessary. The first grading was carried out on day 14 and subsequent gradings were done every 5 days or depending on daily observation.

The main grading apparatus was the grading basin. This apparatus was improvised from the ordinary plastic basin where similar size holes were bored at the bottom of the basin.

The larvae were caught and placed in the basin and with slight upward-downward motion the smaller larvae escaped through the holes while the larger larvae were trapped and separated to another container.

Stocking Density

To encourage healthy growth and reduce cannibal-

ism a set of stocking densities at various larval stages was followed as suggested by Maneewongsa and Tatannon (1982).

Results and Discussion

The survival rate of the first larviculture trial in May 1982 was 30% which produced about 200 000 forty-day-old fry. In 1983, trial cultures using the same method as in 1982 were carried out twice, with survival rates of 45 and 35%, and yields of about 60 000 and 200 000 fry, respectively. These results and the observations on the larval growth were comparable to those earlier achieved in Thailand (Maneewongsa and Tattanon 1982).

From observations on the mortality, most of it seemed to occur during the early stages rather than the later stage of the culture. Maneewongsa and Tattanon (1982) reported higher mortality during the first 7 days and the survival rate was only 37% but no explanation was given.

Some researchers in Thailand believe that small changes in temperature of even 1°C in larval culture tanks could cause stress that leads to mortality in early larval stages. In our larviculture there was no temperature control system and the temperature usually ranged from 28°C in the morning to about 31°C in the evening.

During the later stages of larviculture, most of the mortality was due to cannibalism but this was greatly reduced by grading and adjustment of stocking density.

It was found that the minced fish or prawn flesh given to the larvae during the later stages of culture fouled the tank easily and a lot of water was used to restore the cleanliness of the culture. In order to overcome this problem it seems the only course to take is to develop a suitable pelleted feed for sea bass in future.

In the larviculture trials in 1984, the results showed poor survival rates. High mortality occurred during day 14 to day 18 of the larval stages when *Artemia* nauplii were fed to the larvae.

The larvae showed a general lack of pigment development and were pale in colour. They also showed a lack of appetite and were lethargic before mass mortality occurred.

In this larviculture, the technique used in 1982–83 was repeated, but on many occasions the *Brachionus* cultures were hampered by the failures of microalgae. As a result, most of the time the *Brachionus* cultures depended on the baker's yeast. On some of the days the supply to the larvae was inadequate especially during the trial on 5 April 1984 where too many larvae were reared (4.5 million).

However, the *Brachionus* supply seemed to be sufficient during the trial culture carried out on 16 June 1984, but the same pattern of mortality occurred. As ample amounts of *Artemia* nauplii were given, it seemed the mortality was related to nutrition during the rotifer feeding stage. Watanabe et al. (1983) working on the polyunsaturated fatty acid (PUFA) of rotifer commented that baker's yeast-reared rotifer lacked certain PUFA needed by marine fish larvae and he attributed the fish larval mortality observed in Japan to this factor. Hence our observation on this particular trial could be due to this factor.

Since the first success in Malaysia in sea bass fry production achieved in 1982, the fry produced have been raised in captivity to mature adults. Controlled spawning of these sea bass adults was achieved for the first time in July 1985, and since then adequate sea bass larvae have been produced for hatchery operations without any further need of wild spawners.

The Fisheries Research Institute in Glugor, Penang, would, however, need to continue with its research programs on sea bass propagation and fry production giving particular attention to the following areas: (i) more reliable technique of live food production; (ii) suitable formulated feed for fry and fingerlings; and (iii) disease diagnosis, prevention and control.

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Rearing and Growth of Larval and Juvenile Barramundi *(Lates calcarifer)* in Queensland

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DEVELOPMENT of *Lates calcarifer* hatchery technology in Thailand in the mid 1970s and a concurrent increase in research and management of Australian barramundi stocks contributed to increasing public interest in the potential of the species for commercial culture and for stocking of artificial and natural water bodies. Although Thai *L. calcarifer* culture was reported by Australian researchers (Barlow 1981; MacKinnon 1985) there was little first-hand Australian experience with the various techniques used for breeding and grow-out of the species in Thailand. Because of different physical, biological, and economic conditions in the two countries, drawing inferences from Thai research results when assessing culture potential in Australia was problematic.

In order to increase staff expertise in hatchery and aquaculture procedures and to increase the information on the species under Australian conditions the Queensland Department of Primary Industries undertook a pilot-scale hatchery program, together with tank trials on growth of barramundi fed pelleted diets, during 1984–86. Major features of the program are outlined in this paper and some of the results obtained are briefly discussed.

Sources of Fertilised Eggs

All eggs hatched during the program were derived from populations of barramundi in the Embley and Hey rivers near Weipa, far north Queensland. Fish in these rivers form part of sexually precocious stocks which inhabit northern Cape York Peninsula waters (Davis 1984; R. Garrett pers. comm.).

Eggs for hatchery rearing were obtained primarily through stripping of ripe fish captured on spawning grounds in the Embley River estuary and were fertilised using the dry technique. Several batches of eggs were obtained through hormone induction of freshly captured female fish held in floating net cages in the estuary. Eggs stripped from these fish were fertilised with milt stripped from wild males held in cages, or stripped from freshly captured males and stored under refrigeration for up to 3 days. One batch of eggs was obtained from hormone induction and hand stripping of a captive female fish held with other captive broodstock in a 54-t saltwater tank at the Northern Fisheries Research Centre in Cairns for more than 1 year.

The field program demonstrated the periodic aggregation of barramundi on at least one specific site in the Embley River for spawning and confirmed the close relationship of spawning activity to lunar/tidal cycles (Garrett 1986; MacKinnon et al. in preparation). The location of spawning areas confirmed evidence from larval sampling studies (Davis 1985) that spawning can occur well upstream when salinities are high.

Fertilised eggs obtained at Weipa were incubated overnight in small aerated tanks on site before being transported by air to the Northern Fisheries Research Centre in Cairns for rearing.

Egg Characteristics

Eggs of Embley River barramundi were smaller (mean diameter 0.72 mm, range 0.70–0.75 mm) than those from Thai fish (mean 0.76 –0.78 mm in most months) as reported by Maneewong and Watanabe (1984). The oil globule was also somewhat smaller (0.21–0.23 mm) in eggs of the Australian fish than in Thai fish (0.24–0.24 mm). The eggs sank slowly in sea water (34‰), but even gentle water movement was sufficient to keep them in suspension, and under natural conditions of tidal current they would almost certainly be pelagic rather than demersal. Eggs of barramundi from eastern Papua also exhibited negative buoyancy (Moore 1982) but Thai *L. calcarifer* eggs floated at salinities of 28–31‰ (Wongsomnuk and Manevonk 1973; Maneewongsa and Tattanon 1982a).

Larval Rearing

The pilot hatchery facility was located in an air-conditioned aquarium room and was supplied with salt water through a deep water intake in the adjacent estuarine inlet. Salt water was pumped from the intake through a rapid sand filter to a 54-t covered reservoir

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tank. This allowed settling of sediments and provided some control over short-term fluctuations in supply water salinity. Water drawn from the reservoir to supply the rearing tanks was passed through a series of cartridge filters down to 5μ retention size. Final filtration was by use of a 1μ cloth filter attached to the delivery hose. Fresh water required for salinity adjustment was drawn from the city water supply into outdoor plastic-lined swimming pools where it was allowed to stand for at least 24 hours in order to dechlorinate before use.

During the saltwater rearing phase, which generally lasted for 14–16 days after hatching, the procedures adopted were based on the techniques developed in Thailand and described in National Institute of Coastal Aquaculture (1986). Stocking rates, feeding densities and feeding schedules were similar to Thai practices but water exchange was more frequent with at least 50% of water being exchanged twice daily. For this period salinity in the rearing tanks was maintained at 30–34‰ and temperature ranged from 26 to 27.5°C.

Fertilised eggs or newly hatched larvae arriving in the hatchery were placed in circular, conical-bottomed, fibreglass tanks with a central screened outlet and a capacity of 1200 l. Gentle aeration of incubation tanks was sufficient to keep live eggs in suspension while dead eggs settled to the tank bottom. Incubation period was similar to that reported in Thailand with hatching occurring at 12–18 hours after fertilisation (approximately 17 hours at 28°C). Newly hatched larvae were 1.5 mm in length.

Development and hatching were delayed, and mortality was high. in many batches of eggs transferred by air from Weipa to Cairns. This resulted from physical and/or chemical stress factors during transport. Eggs were sealed in plastic bags for periods of up to 6 hours during transport. Analysis of water from transport bags indicated elevated ammonia levels when eggs were densely packed (MacKinnon et al., in prep.).

After hatching, dead eggs and larvae were removed from the bottom of the tank and the live larvae were maintained in the same tanks for rearing. Continuous gentle aeration was supplied and the tank bottom was cleaned and water exchanged twice daily.

Feeding commenced from about the third day after hatching. Food and feeding schedules were similar to those adopted in Thailand (Watanabe 1982; Maneewongsa and Tattanon 1982b). First food of the larvae was the rotifer *Brachionus plicatilis* which was cultured on *Chlorella* or a mixture of *Chlorella* and baker's yeast. Stock cultures of both algae and rotifer were maintained in the laboratory and bulk cultures for feeding were grown in outdoor circular fibreglass tanks of 1-,2- and 5-t capacities. Feeding of larvae was carried out twice daily and the density of rotifers in the rearing tanks was maintained, when possible, at 10/ml. Small amounts of *Chlorella* culture were also added to the larval tanks to provide food for those rotifers remaining uneaten.

Unreliable supplies of *Chlorella* caused problems during the hatchery program. Sudden collapses of outdoor bulk cultures occurred on several occasions, mainly during very hot periods, or during rainy weather (when it was hard to maintain satisfactory salinities in the culture tanks). Similar problems with production of *Chlorella* have been experienced in Thailand (S. Maneewong, pers. comm.) and Malaysia (A. Awang, pers. comm.).

At 8 days after hatching, feeding with newly hatched *Artemia* nauplii was commenced in addition to feeding rotifer. Density of *Artemia* in rearing tanks was initially 1/ml increasing to 4/ml at 14 days by which time rotifer feeding was discontinued.

From about 14 days after hatching, when the larvae were about 7 mm long, a number of different approaches were adopted to rear the advanced larvae through to the juvenile stage. Some larvae were reared further in salt water in the same tanks and fed on *Artemia* until they were introduced to artificial diets. Other larvae were transferred to fresh water and transported to Walkamin Research Station, inland from Cairns, for further rearing in tanks or earth ponds. Prior to transport, salinity was lowered by partially draining rearing tanks and refilling them with fresh water. Aeration was increased during refilling to assist with mixing. By this method salinity was lowered in three stages from 30–34‰ down to 5‰ over about 18 hours. The larvae were then transferred to plastic bags containing water of 5‰ salinity and transported by road to Walkamin, a journey of about 90 min. On arrival at Walkamin they were placed in fresh water.

Three batches of fish at 16–17 days after hatching were placed in separate 0.1-ha earthen fry ponds at Walkamin Research Station. These ponds had been filled and fertilised to promote plankton growth approximately 10 days prior to stocking. The fish remained in the fry ponds for periods of approximately 25 days and were then harvested for stocking out to Tinaroo Falls reservoir near Walkamin.

Two batches of fish 15 days old were transferred to circular concrete freshwater tanks of 2000 l capacity at Walkamin and were fed at first with live freshwater zooplankton collected from earthen ponds by an airlift operated plankton concentrator as well as live *Artemia* nauplii. At the age of 20 days weaning onto dry pelleted formulated diets was started. Feeding of live plankton was gradually decreased and replaced by dead *Artemia*. At the same time the fish were trained to come to one point for feeding. Once the fish were accepting dead food, small amounts of commercial

salmon starter feed were finely ground and mixed with dead *Artemia* nauplii. This mixture was then offered drop by drop at the normal feeding place. Food was offered three times daily and on succeeding days the proportion of ground salmon starter offered at each feeding was increased. In order to prevent starvation of larvae not yet accepting dead food a small amount of live *Artemia* was added to the tank at the end of some feeding sessions. By 26 days of age, when the fish had reached juvenile stage, the ground salmon starter was eaten readily by nearly all individuals.

The ability to convert fry to artificial food as early as 25 days provides an alternative to the feeding of finely minced fish which is commenced at about this age in Thai hatcheries. The feeding of fish flesh carries risks of pathogen introduction, nutritional deficiencies such as avitaminosis (Kosutarak 1984), and pollution of the rearing container. These risks are reduced or eliminated by the use of formulated foods.

Fish trained to accept dry pellet food in freshwater tanks at Walkamin and in saltwater tanks at Cairns were used in a series of tank-feeding trials which are outlined later.

Larval Development

A daily photographic record of larval development to 14 days after hatching was kept and length samples were taken daily in several batches of larvae. The sequence of larval development followed closely the stages described for Thai fish by Kosutarak and Watanabe (1984). Despite Thai rearing temperatures being somewhat higher than in Queensland the timing of developmental stages was remarkably similar. Distinct development stages which were identifiable in photographs of Queensland larvae and which were synchronous with development in Thai larvae were noted throughout the period of the photographic record.

These included the appearance of rudimentary dorsal and anal fins on day 7 and the appearance of slits in the larval membrane marking the posterior margins of the dorsal and anal fins on day 10.

On the 14th day after hatching the most notable development feature in larvae from both countries was the appearance of rudimentary pelvic fins. Kosutarak and Watanabe (1984) recorded larval development in greater detail than was done in the Queensland study and concluded that the juvenile stage in Thai fish was reached at a total length of 8–12 mm which corresponded to an age of about 3–4 weeks. The exact time at which the juvenile stage was reached was not investigated in Embley River fish but by 26 days from hatching they were well scaled and were assumed to be juveniles.

Despite the close synchrony of developmental stages there was a marked difference between the growth rate observed in Embley River larvae and the daily size increments recorded in Thailand by Kosutarak and Watanabe (1984). The size of newly hatched larvae in the Queensland study (length 1.5 mm) was similar to that in Thailand but by about a week from hatching a size difference started to become noticeable, with the Embley River fish starting to become larger than Thai fish of the same age. This size differential increased as development proceeded and, although there were slight variations between batches of larvae, Embley fish were consistently larger than Thai fish of the same age by the time they were 2 weeks old.

Ruangpanit et al. (1984) found that fry grew faster at lower densities while Maneewong et al. (1984) noted the effects of food density on growth. The relatively fast growth rate experienced in the Queensland trials may have resulted from differences in rearing conditions (e.g. larval density, feeding rates, or rate of water exchange). Alternatively it may be a consequence of genetic differences in larval growth potential between *L. calcarifer* stocks.

Hatchery Survival

High mortalities were experienced during and after transport of eggs from Weipa to Cairns (MacKinnon et al., in prep.). The poor condition of eggs and larvae on arrival in the hatchery was a major limitation to the number of fry produced during the program. Of larvae surviving to 1 day after hatching, survival over the ensuing period of 14 days was usually between 20 and 50%. In several batches of fish a condition which typically became apparent at between 12 and 14 days of age was responsible for near total mortalities over a period of several days. The first signs of this condition to be noticed in larvae included pale greyish colouration and abnormal swimming in a darting or corkscrewing fashion. In many cases affected larvae came to the surface where a swollen, shiny swimbladder could sometimes be observed. In the first occurrence of this syndrome, in November 1984, there was no evidence that bacterial or viral disease caused the mortality but there were some indications from histological examination that a toxic agent, possibly ammonia, might be responsible (J. Humphrey, J. Langdon, pers. comm.). Regular monitoring of ammonia levels in rearing tanks showed that this was unlikely to be the cause when a similar condition recurred during 1985–86. Tests for common pesticides and heavy metals in supply water and in food organism cultures failed to positively identify any causative agents. Examination of large numbers of affected fish led to a possible alternative explanation of the syndrome which was related to larval feeding practices (L. Rogers, pers. comm.). Various combinations of the following symptoms were visible under a low-power microscope: a distended or burst urinary bladder; haemorrhaging and prolapse of the rectum;

slackening of the posterior abdominal wall; abnormally shaped swimbladder; enlargement, haemorrhage, and occasional rupture, of the spleen; occlusion and enlargement of the posterior intestine prior to the intestinal/rectal valve junction; and faecal ribboning and large faecal pellets containing *Artemia* cysts and partially digested nauplii.

It was postulated that a combination of overfeeding on *Artemia* nauplii and the simultaneous ingestion of cysts may have led to an intestinal blockage which in turn led to the other elements of the conditions. Distention of the intestinal wall, anterior to the ilio-rectal valve, squashed and displaced adjacent organs causing haemorrhage in the kidney and spleen. Eventually the large mass blocking the intestine was squeezed through into the rectum which distended to compress the urinary bladder, rendering it unable to fill and release urine. Once defaecation finally occurred the urinary bladder filled rapidly with the urine backlog, in some cases rupturing and in others becoming detached from connective tissues shared with the posterior abdominal wall and the rectum. This allowed slackening of the posterior abdominal wall which in turn allowed the swimbladder to assume a rounded shape causing the observed buoyancy difficulties and abnormal swimming behaviour. While constipation caused by *Artemia* cysts is probably a major factor in the development of this syndrome, the possibility that other nutritional or toxic factors were involved is recognised.

Growth and Survival in Fry Ponds

Of the three batches of fish placed in fry ponds at Walkamin, only one batch consisted entirely of healthy fish. From this batch of 18 000 larvae, 50% were harvested as fingerlings after a period of 25 days. Growth in the pond was rapid. Larvae were stocked at 16 days and approximately 8–10 mm TL. A sample taken from the pond 18 days later had a mean length of 33 mm and when the pond was drained after 25 days growth the fish were 42 days old and had a mean length of 50 mm (range 18–70 mm).

Subsequent stockings to the two other fry ponds included a large percentage of fish showing symptoms of the disease mentioned above as causing severe mortalities in larval rearing tanks. Only about 30% of these fish appeared to be healthy at the time of stocking, and survival over the pond rearing period (20 and 28% in the two ponds) was somewhat less than in the first batch of fish. Growth rate, however, was approximately the same and when harvested after 28 days the mean length of fish in the two ponds was approximately 50 mm (range 20–87 mm).

Similar survival in fry ponds has been experienced elsewhere. Barlow (1981) mentions a case in Thailand in which 20-day-old fry were transferred from 20‰ salinity to a fresh water pond. When the pond was drained after 4 months 30% of the stock were recovered.

The encouraging results obtained in the pilot program suggest further investigation into pond rearing of advanced larvae is warranted and that, in the Australian context at least, this method could well be as cost effective as continuation of Thai tank-rearing techniques through to the juvenile stage. Apart from considerable savings in labour, pond rearing from the advanced larval stage might offer other advantages in an Australian hatchery where the production season might be relatively short compared to hatcheries in Southeast Asia. As previously suggested (MacKinnon 1983) the transfer of larvae to ponds at about 14 days of age might facilitate optimum use of available facilities as these larvae would vacate tanks at the time when the succeeding fortnightly spawning period was due and the next batch of larvae was expected.

Rearing of Juvenile Fish on Artificial Dry Pellet Diets

A number of different trials were conducted with juvenile barramundi held in tanks and fed on formulated pellet diets. The trials provided information on the types of food best suited for the species, suitable feeding regimes, and the effects of salinity and temperature on growth and food conversion. Data from these trials are being prepared for publication (Tucker et al.; Russell and Rasmussen; MacKinnon et al.) and are summarised briefly below.

Barramundi to be used in feeding trials were weaned onto an artificial diet by the age of 25–26 days at a length of approximately 13–15 mm. From this time on only formulated foods were offered. The food offered in the initial period was a commercial salmon starter containing 52% protein and 16% fat. This was given in the form of fine crumbles which were increased in size at approximately 10-day intervals as the fish grew.

A batch of fish maintained in fresh water, outdoor concrete tanks at Walkamin and fed salmon starter crumbles reached approximately 90 mm TL and 10 g mean weight at 65 days after hatching. At this stage they were able to accept short pellets of 3.2 mm diam, and a sample of fish was selected for use in a trial comparing two experimental diets containing the same protein content but different levels of fat. The trial commenced at 66 days of age and ran for 76 days in indoor freshwater tanks at a mean temperature of about 25°C. At completion of the trial the fish, now 142 days old, had a mean weight of 60 g and a mean total length of 155 mm. The higher fat diet gave a better food conversion ratio of 0.93:1.

Another batch of fish from a separate spawning were also kept in outdoor freshwater tanks at Walkamin and fed on salmon starter until they were 130 days old. At this stage 60 fish (mean length 165 mm, mean weight

71 g) were transferred to indoor freshwater tanks at a mean temperature of 25.5°C, for a trial which compared growth and food conversion in fish fed once daily, and fish fed twice daily with salmon starter. Duration of this trial was 43 days at the conclusion of which the mean size of fish had increased to 210 mm and 151 g. There was little difference in growth between the treatments but food ratio (1.09:1) was lower in fish fed once daily.

Survival during both the above trials was 100%. Detailed results will be reported by Tucker et al. (in prep.).

After completion of the feeding frequency trial, 30 fish were retained in freshwater tanks and fed to satiation once daily with commercial salmon starter. The fish were weighed and measured at 181 days from hatching (mean length 210 mm, mean weight 160 g) and again at 314 days after hatching when the mean length and mean weight were approximately 310 mm and 420 g, respectively.

A batch of fish maintained in saltwater tanks at the Cairns laboratory were weaned onto a commercial salmon starter diet and were used in two different trials.

One of these trials compared growth and food conversion on six different experimental diets with similar protein content but varying proportions of fish meal. Eighty four fish 17 g mean weight were used in the trial which ran for 57 days at a mean water temperature of 27°C. At completion of this trial the fish in the fastest growing treatment had a mean weight of 72.5 g. The best food conversion ratio obtained in this trial was 1.07:1. The trial will be reported in detail by Tucker et al. (in prep.).

The other experiment carried out in the Cairns hatchery compared growth and food conversion of fish fed a commercial salmon starter diet in fresh water and in salt water at three different temperatures (22, 27, 32°C). At the start of the experiment the fish were 80 days old with a mean weight of 4.7 g. Growth was fastest at high temperatures but there was no significant difference in growth rate between fresh and salt water. Food conversion was most efficient at 27°C (mean 1.02:1). At completion of the 51-day trial the mean weight of fish held at 22°C was 15 g, that of fish held at 27°C, 46 g, and at 32°C, 63 g. This trial will be detailed by Russell and Rasmussen (in prep.).

Commercial grow-out culture of *L. calcarifer* in Southeast Asia is presently based on the availability of regular supplies of relatively cheap trash fish. MacKinnon (1983, 1985) suggested that costs of Australian barramundi culture using trash fish as feed might well be prohibitive. It was suggested that pellet foods might lower costs of grow-out culture although doubts were expressed about the likelihood of suitable diets being developed.

While the extrapolation of results from small-scale tank trials should be undertaken with caution, the growth rates and food conversion ratios obtained in this pilot program suggest good potential for aquaculture of the species on dry pellet diets. Specimens held in tanks at around 25°C showed the potential to reach marketable size within 12 months of spawning.

Considering the relatively low temperatures (approximately 25°C) at which the Walkamin feeding trials were carried out, the growth rates compare favourably with results of pellet feeding trial elsewhere (Chou 1984; Aquacop in press) and with the growth of fish cultured on a trash fish diet (Sirikul 1982; Sakaras 1984). While growth rates at 25°C were satisfactory this temperature is probably below the optimal range for culture. The slow growth of barramundi held at 22°C indicates that potential for culture at ambient water temperatures in Australia is probably restricted to areas lying well within the tropics.

Growth of fish produced in the hatchery program and stocked in December 1985 to Lake Tinaroo, a 3300-ha reservoir near Walkamin, was much faster than that of the tank-reared fish. The 14 000 fish released into the impoundment were approximately 40 days old and 50 mm TL. In a gillnet sample of 30 fish taken in early June at approximately 210 days from hatching mean length was 340 mm and the mean weight exceeded 540 g. This is larger than most size estimates for Australian and Papuan wildstock *L. calcarifer* at the age of 1 year (Garrett and Russell 1982; Reynolds and Moore 1982; Davis and Kirkwood 1984). In field studies of wild barramundi stocks, Davis and Kirkwood (1984) showed that growth of age 0+ fish was very seasonal and that most of the year's growth was completed during the first few months. Thus it is possible that the fish stocked to Lake Tinaroo may grow little during the remainder of the year and monitoring of growth is continuing.

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Culture — Pond

Culture of Sea Bass *(Lates calcarifer)* in Earthen Brackishwater Ponds

Edward Danakusumah and Asmin Ismail*

Sea bass *(Lates calcarifer)* is an esteemed fish in Indonesia because of its delicious taste. It has a relatively high price of between Rp 2000.00** (at the pond) and Rp 3000.00 (at the fish market) per kg, the most expensive finfish (Danakusumah et al. 1986).

In 1983, the sea bass production in Indonesia was 14 158 t. It contributes 0.68% of the total fisheries production (Anon. 1985). Most of the sea bass production is caught from the sea and only a small part is produced from coastal aquaculture, as a by-product of milkfish (*Chanos chanos*) culture. In traditional brackishwater culture, wild shrimps, sea bass fry and others usually enter the milkfish culture ponds during water filling (Schuster 1950; Brown 1977). Wild shrimps are not purposely introduced to the pond but their presence is welcomed because of their value to the market. On the other hand, the presence of sea bass is not welcomed because they prey on the shrimp, and possibly on the milkfish, thus reducing the fishermen's income.

Growth of wild sea bass in the milkfish culture pond is relatively fast. Danakusumah et al. (1986) reported that within 5 months, wild sea bass fry could grow to a maximum size of 517 g. Moreover, they reported that 12.7 kg sea bass, or 4.3% of the total production, was harvested from a 10 000 m^2 milkfish culture pond. Sea bass seems to be one of the promising species for finfish culture in Indonesia (Chan 1981) as well as in Pakistan, India and Thailand (Bardach et al. 1972).

The study proposes a semi-traditional brackishwater culture method applied to sea bass.

Materials and Methods

The experiment was conducted in four earthen brackishwater ponds (100 × 50 × 1 m). Ponds were equipped with wooden sluice-gates and bamboo screens. Bamboo screen (2 cm in opening size) was set in front of the gate. The ponds were sun dried for 2 weeks until the bottom soil became very dry. Experimental fish were collected locally using nets, and were kept in impounding nets at the pond and trained to eat formulated feed as moist pellet 'trash fish.' After they were accustomed to eating such feeds, they were set free in the experimental ponds at an initial density of 500 individuals per pond. The average body weight was 83.3, 82.1, 84.5 and 85.6 g for those placed in Experimental Ponds A–1, A–2, B–1 and B–2, respectively. The fish in A–1 and A–2 were fed with formulated feed and those of the B–1 and B–2 with 'trash fish.' The composition of the feed was (%): fish meal 65, soya 12, corn 3, rice bran 2, starch 15, vitamin mix 2, and mineral mix 1. The approximate analysis of the formulated feed was (%): crude protein 41.5, crude lipid 3, carbohydrate 25, fibre 3, ash 19.5, and water 8. Daily feeding rate was 2% of estimated total body weight served every morning.

Water exchange was done during the high and low tides by opening and closing the sluice gate. Wild shrimps and other fish fries were expected to enter the ponds as additional natural feed for the sea bass. The sea bass were harvested after 5 months.

During the experiment, pH, water temperature and dissolved oxygen were monitored.

Results and Discussion

'Relative' food conversion ratios were 2.93, 3.03, 1.39 and 1.12 (0.340, 0.330, 0.719 and 0.893 in 'relative' food efficiencies) for those cultured in A–1, A–2, B–1 and B–2, respectively. Chan et al. (1985) found that food conversion ratio of sea bass cultured in net cages fed with 'trash fish' ranged between 7.6 and 8.4 (0.132 and 0.119 in food efficiency) while Sugama and Eda (1986) using the same method found that the food conversion ratio ranged between 7.1 and 8.5 (0.131 and 0.118 in food efficiency). The present data suggest that our feeds are more efficient than those of Chan et al. (1985) and Sugama and Eda (1986). We believe it is caused by the presence of natural food organisms such as shrimp and other fish fry which grew naturally at the ponds.

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** 1 US $ = Rp 1100.00

Wild organisms living in the ponds included tilapia, mullet, spotted scats, mud skippers, mud eels, various species of shrimp, yellow prawn and mud crab. Naturally, Odum (1971) found that production efficiency between secondary trophic levels are between 10 and 20%. Bardach et al. (1972) found that where crustaceans are extremely abundant, sea bass may derive up to 75% of their food from them and perhaps thereby spare other fish to some extent. In the present experiment, it was very difficult to estimate the volume of natural food organisms which had been preyed on by the sea bass.

The organisms included: *Tilapia mossambica, Mugil* spp. *Scatophagus argus, Ambasis* spp., *Periophthalmus* spp., *Panchax panchax, Monopterus albus;* the crustaceans *Penaeus merguiensis, P. indicus, P. semisulcatus, P. monodon, Metapenaeus monoceros,* and *Acetes* spp.; crab, *Scylla serata.*

Average individual daily growth was 1.50, 1.33, 3.58, and 2.65 g for those cultured in A–1, A–2, B–1 and B–2, respectively. Chan et al. (1985) found that average daily growths of sea bass cultured in floating net cages during 152 days fed with 'trash fish' at daily feeding rate of 8% total body weight were 4.32, 4.05 and 4.33 g. Sugama and Eda (1986) found that average daily growths were 4.64 and 6.05 g. Growth and production are dependent on the amount of supplied feed (Bardach et al. 1972).

During the experiment, survival rates were 76.5, 72.2, 79.2 and 85.4% for those cultured in A–1, A–2, B–1 and B–2, respectively. Sea bass are piscivorous, so mortality is possibly caused by their cannibalism. Ruangpanit et al. (1984) found that cannibalism in sea bass begins at 12–15-day-old fry. Sugama and Eda (1986) give survival rates of 88–97% for sea bass cultured in floating net cages. One hundred per cent survival rates have been attained by Chan et al. (1985).

During the experiment, daily changes of pH, water temperature, dissolved oxygen and salinity were 7.7–9.3, 26.1–33.3°C, 4.3–8.5 ppm and 15–30‰, respectively. According to Bardach et al. (1972) ideal pH, water temperature and salinity range between 7.1 and 7.9, 24.0 and 38.5°C, and 10 and 35‰, respectively.

At present, culture of sea bass in Indonesia is not economically sound because of the high price of formulated feed. In order to produce 1 kg of sea bass, about 3 kg of formulated feed is needed. Price of formulated feed is Rp 800.00/kg while the price of sea bass is only Rp 2000.00–3000.00/kg. On the other hand, price of 'trash fish' ranges between Rp 400.00 and 500.00/kg. About 1.4 kg of 'trash fish' is needed to produce 1 kg of sea bass. This seems to be profitable; however, our data on the food conversion ratio of those fed with 'trash fish' leaves some doubt about the soundness of this approach.

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Effect of Stocking Density on Growth and Survival of Sea Bass *(Lates calcarifer)* in Ponds

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AQUACULTURE or the farming of marine aquatic organisms such as fish, crustacea and molluscs, is still at an early stage of development in Malaysia (Ong 1983). Some of the species that are presently being cultured are cockle, penaeid shrimps, mussel, crab, oyster and finfishes. In the culture of finfishes the sea bass (*Lates calcarifer*) and grouper (*Epinephelus tauvina*) are widely cultured.

Marine species that are normally cultured in ponds are penaeid shrimps and the above-mentioned finfishes particularly the sea bass. However both of these finfishes are preferred for culturing in cages (Ubaidillah 1986). In view of its potential of becoming an alternative species for those already practising pond shrimp farming, and also the limitation of suitable sites for further expansion in cage culture (especially on the East Coast of Peninsular Malaysia which is well known for its hazardous weather), the Department of Fisheries of Malaysia is continuing research on finfish pond culture at its Brackishwater Research Center in Gelang Patah, Johore.

Stocking density is believed to have an affect on the growth and survival rate of the fish. One of the factors that causes low survival is cannibalism, which may be induced by overcrowding, hunger, and malnutrition. Higher stocking is believed not only to induce cannibalism but also to retard the growth of the fish.

Thus an optimal stocking density, one that would maintain good survival and growth rate, needs to be established for sea bass culture in ponds.

Materials and Methods

One of the experiments that is being conducted now in our centre is the effect of stocking density on survival and growth rate of *L. calcarifer* in brackish-water ponds.

Stocking Density

In this trial, two 0.5-ha ponds have been used. Pond A is stocked with sea bass at 3000 pieces/ha and Pond B at 4500 pieces/ha. The pond preparation included drying, tilling, poisoning and liming. No pond fertilisation was carried out.

Seeds

The size of seeds which were obtained from Thailand varied from 5.0 to 10.0 cm with average weight of 7.8 g. The seeds were stocked directly into the prepared ponds as soon as they arrived.

Feeding

The fish were fed with trash fish once a day, preferably early in the morning about 0830 hours. Feeding is never carried out when the water level in the pond is less than 0.5 m. The amount of feed given depends on the size of the fish: <100 g, 8–10%; >100 g, 3–5%.

Feeding was stopped when the fish had reached satiation or whenever it was observed that the fish was not taking the food anymore.

Water Management

The pond complex at the BAC is operated by the tidal system. Water was changed at the rate of 30% daily except during neap tide when it is not possible to do so. This normally extends to about 3–6 days for each month. Water depth was maintained throughout the experiment at 0.8–1.0 m.

Collection of Data

Data for the body weights were collected every month. However the duration between samplings varied slightly after taking the stress factor into account, i.e. during bad weather or whenever it was observed that water quality was not too good. Sampling was carried out using cast nets. Survival rate data for each pond was observed and recorded during the final harvesting.

Monitoring of water quality parameters such as pH, salinity, dissolved oxygen and temperature, was done daily in the early morning.

The ponds were harvested when the average body weight of fish had reached about 300–400 g each. Those fish which were stunted (<200 g) were transfer-

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red to a 0.15-ha pond for an additional culture period of 4 months.

Table 1. Growth rate of sea bass cultured in ponds.

Culture (period) (days)	Body weight (g)			
	Pond A (3000 pieces/ha)		Pond B (4500 pieces/ha)	
	Range	Average	Range	Average
Stocking	4.3– 13.1	7.8	4.3– 13.1	7.8
35	8.6– 60.5	26.5	4.1– 23.3	10.3
64	19.0–154.0	68.4	6.4– 95.0	22.8
95	45.0–204.5	116.5	20.5–224.0	82.9
127	90.0–420.0	186.7	27.5–358.0	134.7
160	73.0–490.0	223.8	51.0–312.0	136.5
193	110.0–715.0	312.0	25.5–660	171.6
228	63.0–850.0	369.0	31.0–960.0	225.5

Fish production in the two experimental ponds

	Pond A	**Pond B**
Number stocked	1500 pieces	2250 pieces
Number recovered	1146 pieces	669 pieces
Survival rate	76.4%	30.4%
% of fish ⩾ 200 g	66.6	53.6
% of fish < 200 g	33.4	47.4
Total weight harvest	498.6 kg	202.7 kg
Production/ha(kg/ha)	997.3	405.3
Total feed (kg)	2852.0	1581.0
FCR	5.8	8.5

Table 2. Growth rate for sea bass cultured in ponds.

Culture period (days)	Body weight (g)	
	Range	Average
Stocking	31.0–120.0	68.2
43	49.0–110.0	68.5
68	90.0–270.0	170.3
94	110.0–520.0	245.5
124	87.0–570.0	323.3

Fish production in reculture of stunted fish

Stocking rate	2000 pieces/ha
Number stocked	300 pieces
Number recovered	281 pieces
Survival rate	93.6%
% of fish ⩾ 200 g	71.2
% of fish < 200 g	28.8
Total weight harvested (kg)	97.8
Production/ha	652.0 kg
Total weight of food	480.3 kg
FCR	6.2

Results

After a culture period of about 7.5 months, the fish were harvested. The results of the experiment for growth performance, and fish production are given in Tables 1 and 2.

Discussion

The decision to harvest was made after 7.5 months culture period when it was found that the difference in size between the fish within the population of the same ponds varied significantly. This was done to avoid a further deteriorating condition which could have resulted in greater loss of fish through cannibalism.

The size range is quite wide at harvest (Table 1), especially in the pond with the higher stocking. There is also a higher percentage of fish below 200 g within the population pond B (47.4%) compared to pond A (33.4%). In this situation it would be expected that the occurrences of cannibalism would be much greater in the higher stocking as shown by the survival rate experienced in higher stocking (30.4%) compared to lower stocking (76.4%). As a result, the total harvest is higher in the lower stocking pond.

Water Quality

The water quality for both ponds was similar and suitable for sea bass culture (Trino 1986).

Growth Rate

The harvest data show that after 228 days of culture the average body weight of fish which were stocked at 3000 pieces/ha is 365.9 g compared to 225.5 g at 4500 pieces/ha stocking.

Considering that the seed were from a common stock, feed quality and feeding rate used in the trial have been the same in both ponds, water quality in both ponds was similar and pond preparation and management were the same, it is therefore likely that the difference in growth between fish populations in ponds would be a result of stocking density.

A comparison of the growth rate attained by our trials and that achieved in Thailand using stocking densities between 3125 and 6250 fish/ha (Sirikul 1982) shows that the growth rate in Thailand is within the rate we achieved in our trials.

Survival Rate

The survival rate (76.4%) for the trial with stocking density at 3000 pieces/ha is much higher than that with stocking density at 4500 pieces/ha, which is only 30.4%. The low survival may be due to cannibalism as there were no signs of fish mortality occurring during the trial. As has been discussed earlier the chances of cannibalism are relatively greater with increasing stocking density.

Stunted Fish

Harvest results from the trial ponds indicate a greater percentage of stunted fish (those below 200 g) occurs in ponds stocked at a higher density (4500 pieces/ha). The data in Table 2 show the results obtained from the experiment. Almost 70% of the stunted fish, after reculturing for 4 months, averaged

323.3 g. Therefore, normal growth can be achieved even by stunted fish providing better conditions are available. This includes absence of competition for feed.

Feed Conversion Ratio

The trial results show FCR values of 5.8 and 8.5 for the low and high densities respectively. Sirikul (1982) reported that average FCR for cultured sea bass varied from 7 to 10.

The lower FCR obtained in the lower stocked trial (3000 pieces/ha) shows that the feed may have been more efficiently utilised as mentioned earlier.

Conclusion

The trial conducted has shown the expected effects of stocking density on growth and survival rate. A stocking density of 3000 pieces/ha yields a better harvest than the 4500 pieces/ha density. Reducing the stocking density from 4500 to 3000 pieces/ha has the effect of increasing both the growth and survival rate. The optimal stocking density will have to be determined through further research, which will in turn maximise economic returns to the fish farmers.

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Sea Bass *(Lates calcarifer)* Research at the Brackishwater Aquaculture Center, Philippines

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In the Philippines, particularly in Iloilo and other provinces of Panay Island of the Visayas group, interest in the culture of sea bass *(Lates calcarifer)* has long been expressed by fish farmers who have occasionally harvested sea bass in their milkfish and prawn ponds.

Sea bass fry are occasionally caught together with other species of fish that inhabit the coastal areas, mangrove swamps and the estuarine region during the gathering of milkfish fry which starts from late February or early March to November. The sea bass fry finds its way into the milkfish ponds during flooding which is usually done every fortnight when water in the milkfish ponds is changed (Aure 1982).

The Filipino fish farmers, having observed the feasibility of culturing sea bass in ponds, stocked some of their ponds with sea bass on what is called 'put-and-take' method. This is done by stocking any number of fish into the pond and allowing them to grow, subsisting only on what is available in the pond. Some fish farmers would buy fingerlings and release them in the ponds as they receive them (Fortes 1985).

Although there are existing culture techniques in other countries, particularly in Thailand, it is obvious that sea bass culture has still much room for improvement. In the Philippines there is a need to develop culture techniques because the methods used in other countries are mostly dependent on trash fish which is non-existent here (Fortes 1985).

Realising this, formal work on sea bass was initiated in the Philippines at this Center in 1981. The program for sea bass includes several phases as follows: Phase 1 — Development of Culture Techniques for Sea Bass (ponds, cages, pens, etc.). Under this phase, continuous work on developing and refining culture techniques will be done one after another. This phase started in 1982 and will continue to 1989; Phase II — Development of Management Procedures for Rearing and Breeding of Sea Bass. This phase is programmed to be completed in 5 years (1985 to 1989); Phase III — Refinement of Methods and Techniques for Artificial Breeding of Sea Bass. This is also programmed to be completed in 6 years (1985 to 1990); and Phase IV — Development and Refinement of Sea Bass Fingerling Production Techniques (1986 to 1990) (Fortes 1985).

This paper reviews the various studies on sea bass conducted at the BAC. The main objective is to present in capsule form the past or completed research and give an overview of prioritised and immediate needs for sea bass research.

The past and completed research on sea bass at the BAC was concentrated on the first phase of the program on the development of culture techniques.

Stocking Density in Monoculture Ponds

Preliminary trials on the culture of sea bass in ponds were conducted during the rainy and dry season using stocking densities of 1000 and 2000 fish/ha. Trash fish was given at 5% body weight (dry weight basis) and screens installed allowed the entry of shrimps and small fishes that served as additional food.

In the first trial, sea bass fingerlings and post-fingerlings coming from the wild were trained to eat trash fish for 28 days in the fibreglass tanks prior to their release in the ponds. Due to the difficulty of obtaining the right size of fingerlings, size range and interval of stocking were affected. Sea bass stocked at 2000/ha with an initial mean weight of 221.5 g were cultured for 94 days (harvest weight 351.5 g) and those stocked at 1000/ha with an initial weight of 8 g (harvest weight 155.3 g) were cultured for 166 days.

In the second preliminary trial, the sea bass used were those taken after the inventory of the first preliminary trial and fish of similar size groups were added to complete the number required by the various treatments (the fish stocked at 1000/ha had a mean weight of stocking of 153.5 g, and harvest weight of 219.5 g; comparable figures for the fish stocked at 2000/ha are 302 g and 358.5 g).

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In general, growth rate was slow, although faster growth rate in terms of daily weight increment was observed in replicates with bigger fish, except for one in the 2000/ha stocking density which showed almost no growth. Results indicated that during the wet season, the daily weight increment of sea bass was higher regardless of size (Fortes 1985).

Two experimental runs similar to the preliminary runs were also conducted to determine the optimum stocking density of sea bass. In the first trial, the stocking densities tested were 1500, 2500, and 3000 fish/ha using trash fish at 10% body weight (wet weight basis). In the second trial, the stocking densities tested were 500, 1000, 1500, and 2000/ha using fish from the previous trial plus those in the holding ponds. These were given trash fish at 5% body weight based on dry weight of feed and later adjusted to 3% (Table 1).

1.2 m. The stocking densities tested were 15, 30, 45, 60 and 75 fish/cage. Trash fish was given at 5% body weight based on dry weight of feed and harvest was done after 90 days.

Highest weight increment (1.86 g/day) was observed at a stocking desnsity of 15 fish/cage with a mean weight of 240 g. Lowest weight increment (1.2 g/day) was observed at stocking densities of 60 and 75 fish/cage with mean weights of 156.7 and 155 g respectively. In general, the mean weight of fish decreased as stocking density increased from 15 to 75 fish/cage.

Figure 1 shows that in all treatments the mean weight of sea bass continued to increase from day 15 to day 90 except in treatment V (75 fish per cage), wherein the mean weight started to slow down at day 45, which demonstrated clearly the effect of crowding on fish growth (Dimaano 1983).

Table 1. Stocking and harvest data of sea bass cultured in brackishwater ponds at various stocking densities.

Pond No.	Stocking density	Mean weight (g)		Mean weight gain (g/day)	Percentage survival	Production (kg/ha)
		Stocking	Harvest			
127 days — July–November 1982						
A–15	1500/ha	7.6	77.0	0.54	64	73.92
A–11	1500/ha	8.2	92.0	0.65	100	138.00
A–12	2500/ha	45.4	124.0	0.61	76.8	238.10
A–13	2500/ha	59.7	120.0	0.47	39.0	117.00
A–17	3000/ha	22.4	93.0	0.55	35.0	97.65
A–18	3000/ha	25.8	55.0	0.24	93.0	154.45
161 days — February–July 1983						
A–15	500/ha	173	331	0.98	96	158.9
A–20	500/ha	194	461	1.66	100	230.5
A–6	1000/ha	174	398	1.39	90	358.2
A–12	1000/ha	72	250	1.11	96	240.0
A–10	1500/ha	134	374	1.49	68	381.5
A–13	1500/ha	115	244	0.80	72	263.5
A–11	2000/ha	69	260	1.19	90	486.0
A–19	2000/ha	165	280	0.71	82	459.2

Source: Fortes 1985.

A clear relationship between stocking density and fish production was demonstrated, i.e. fish production increased as stocking density increased. Furthermore, survival decreased as stocking density increased and the daily weight increment was inversely related to stocking density.

The highest production was always attained in the 2000/ha stocking density. Below and above the 2000/ha stocking density fish production dropped, suggesting that figure as the desirable stocking level.

Stocking Density in Cages

A study on the culture of sea bass in cages was done using nylon nets with mesh size of 0.5 inch (1.27 cm) supported by a wooden frame measuring 2 × 1 ×

Survival was 100% at stocking densities of 15, 30, and 45 fish/cage, while at 60 and 75/cage, survival was 91.1 and 89.3% respectively. Results also showed that as stocking density was increased from 15 to 75/cage, production also increased from 3.6 to 11.6 kg/cage. The effect of increasing stocking densities on production of sea bass in cages was positive at least under conditions of the experiment; fish produced were smaller but still very acceptable in the market (Dimaano 1983).

Food Types

Due to the limited supply of trash fish in the Philippines, a study was conducted to determine a practical alternate food. The following were tried:

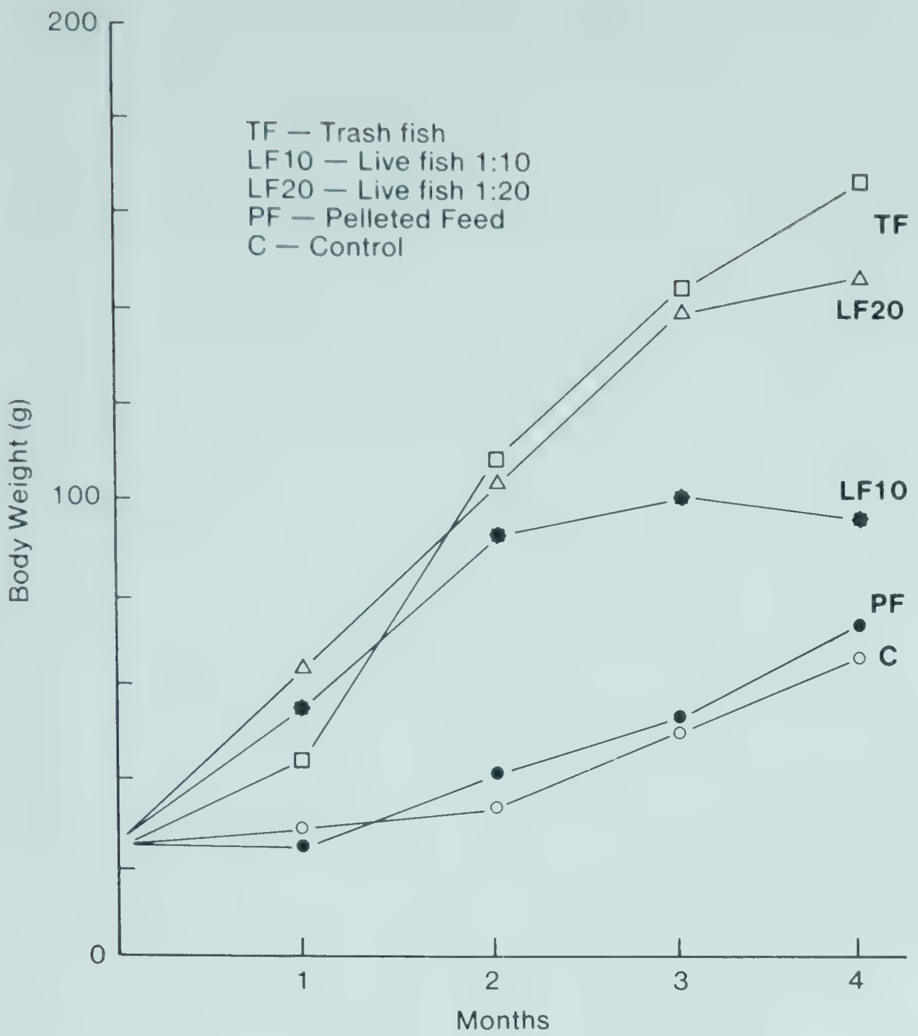

Fig. 1. Growth curves for sea bass juveniles fed with various types of food.

pelletted feed containing 35% crude protein; live tilapia at sea bass-tilapia ratios of 1:10 and 1:20; trashfish; and no feeding, fish dependent on what is available in the pond.

The growth curves of sea bass fed with various types of food are shown in Fig. 1. The highest growth after 4 months was obtained by fish fed with trash fish although growth rate during the first month was slightly lower than those given live food. This could be due to either sampling error, because sea bass manifest uneven growth, or to the delayed response to feeding of trash fish as has been observed with fish coming from the wild in the previous trials. Growth of fish in the 1:20 sea bass-tilapia ratio paralleled that of the treatment fed with trashfish. The growth in the sea bass:tilapia 1:20 ratio approximated that of the sea bass 1:10 ratio during the first 2 months, but was significantly lower during the third and fourth months. This could be explained by the presence of more tilapia to be preyed upon in the higher ratio (Avance 1984).

Acceptability of dry pelleted feed was unfavourable. Growth of fish fed pelleted feed and those not fed were lower than other treatments but were not significantly different from each other.

There is no significant difference in survival among treatments indicating that the different types of food tested had no significant effects on survival of pond-reared sea bass.

Mean survival of tilapia from the two live fish food treatments was generally low. The very low survival of tilapia in the 1:20 ratio compared to the 1:10 ratio can be attributed to its relatively high stocking density which increased the probability of preying by the sea bass (Avance 1984).

Significant differences in total production were found among treatments. Mean total production in the sea bass:tilapia (1:10 and 1:20) treatments was considerably increased from 161.8 kg/ha and 140.7 kg/ha to 918.15 and 806.7 kg/ha respectively when the tilapia harvested were accounted for.

It is evident that live fish food treatments resulted in higher yields per hectare. This looks promising for sea bass farming in the Philippines because the abundance of tilapia can compensate for the lack of trash fish.

Polyculture of Sea Bass and Tilapia

Based on the idea that sea bass could serve as predator to control tilapia reproduction in ponds, a study was done to evaluate the potential of sea bass as predator on young tilapia and at the same time determine the most effective sea bass-tilapia combination.

Tilapia was stocked at 10 000/ha at a male: female ratio of 1:3 and the number of sea bass was adjusted to fit the ratio of 1:20, 1:15, and 1:10 (sea bass: tilapia). The treatments used were the following.

Treatment	Ratio	No. of Sea bass/ha	No. of Tilapia/ha
I	1:20	500	10 000
II	Control	500	0
III	1:15	660	10 000
IV	Control	660	0
V	1:10	1000	10 000
VI	Control	1000	0
VII	Control	0	10 000

Results after a culture period of 118 days for the tilapia and 87 days for the sea bass showed that the daily weight increment of tilapia increased as more sea bass was added to the 10 000 tilapia population and the daily weight increment of sea bass increased as the sea bass-tilapia ratio was increased from 1:10 to 1:20.

The percentage of young tilapia at harvest decreased from 8.3 to 1.8% as the number of sea bass was increased from 500 to 1000/ha. This indicates the effective role of sea bass in the reduction of tilapia young in the population (Fortes 1985).

Production of marketable size tilapia in treatments where sea bass and tilapia were combined were not significantly different from the all-tilapia treatment, however, the additional crop of sea bass in the sea bass-tilapia combination made tilapia culture more attractive.

Production of sea bass among the different sea bass-tilapia combinations shows that only the 1:15

ratio is significantly different from control. Total production in the 1:15 ratio is also significant compared to the rest of the treatments, pointing to the advantage of 1:15 sea bass-tilapia ratio over the others.

Results strongly indicate that the sea bass-tilapia combination could be beneficial, and this trial shows that the 1:15 sea bass-tilapia ratio appears very promising (Fortes 1985).

Another study on the combination of sea bass and tilapia was done using 1160 sea bass/ha and 22 500 tilapia/ha (treatment I), but still maintaining the ratio of 1:20 (sea bass: tilapia). Treatment II had 1160 sea bass and zero tilapia per hectare, and treatment III, 0 and 22 500 respectively. It was thought that although the 1:15 ratio appeared to have more advantages over the 1:20 in the first trial, increasing the number of tilapia in this trial could adequately support the sea bass population of 1160 and significantly increase the total production.

Results show strong indications that the stocking densities used have a negative effect on sea bass even if food in terms of young tilapia was not limiting. The growth attained by sea bass in treatment I (0.5 g/day) was significantly higher than that of treatment II (0.16 g/day), indicating that food was not limiting and that the benefits derived by the sea bass in the sea bass-tilapia combination were still demonstrated.

The survival of sea bass was high, 92.5% and 97.7% for treatments I and II respectively, but production was low, which seems to indicate that the stocking density used in the sea bass-tilapia combinations may have exceeded the density that could be tolerated by sea bass to normally respond to environmental pressures (Fortes 1985).

Tilapia production in the sea bass-tilapia combination (831.2 kg/ha) was lower than that of the tilapia only treatment (959 kg/ha) indicating that the sea bass-tilapia combination did not benefit the tilapia production.

Total production in treatments I (935.5 kg/ha) and III (959 kg/ha) are not significantly different. However, in treatment I the additional crop which is the sea bass is more expensive than tilapia.

Based on the results, sea bass-tilapia polyculture has promise but the density of each fish has to be carefully considered. Using the information from the two trials the sea bass-tilapia ratio of 1:15 could be considered as the most effective ratio at stocking densities of 10 000 tilapia/ha and 660 sea bass/ha (Fortes 1985).

Sea Bass Research at BAC

The present work on sea bass at the Brackishwater Aquaculture Center is concentrated on the other phases of the sea bass program discussed earlier, however, work is being done in developing and refining culture techniques.

Among those recognised as priority areas for research are rearing and spawning of sea bass broodstock, improvement of larval collection techniques, development of natural and/or artificial food for sea bass larvae, development of techniques for fingerling production, and development of artificial feeds for culture of sea bass in grow-out ponds and cages. It is considered that with the availability of fish seed the sea bass industry in the country will flourish.

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Status of Sea Bass *(Lates calcarifer)* Culture in Malaysia

Ali bin Awang*

THE culture of sea bass *(Lates calcarifer)* is a very recent development in Malaysia. It was only in the mid 1970s that sea bass culture began, using wild or imported fry and floating net-cages set up in protected coastal waters. Larval propagation of the sea bass in Malaysia (based on wild broodstock) was first developed by the Fisheries Research Institute situated in Glugor, Penang, in 1982, while the first spawning of sea bass broodstock raised in captivity was achieved in Malaysia in July 1985. So far, only one private commercial hatchery situated in the state of Kedah is operational in Malaysia, based on the hatchlings produced by the hatchery of the Department of Fisheries, Malaysia, situated in Tanjung Demong, Trengganu.

The Fisheries Research Institute (FRI) of the Department of Fisheries, Ministry of Agriculture, Glugor, Penang, has a unit responsible for research on hatchery propagation, larval feed development and cage culture of sea bass in Malaysia. The Brackishwater Unit of the FRI situated in Gelang Patah, Johor, is responsible for the research and development of sea bass grow-out in coastal ponds (Ong 1985).

The Extension Branch of the Department of Fisheries, Ministry of Agriculture, Kuala Lumpur, is responsible for all extension services, in promoting aquaculture development, for sea bass as well as other species. The Extension Branch also operates the Coastal Finfish (Sea Bass) Hatchery in Tanjung Demong, on the east coast of Peninsular Malaysia, and organises training on coastal aquaculture conducted at the Brackishwater Aquaculture Centre situated in Gelang Patah, Johor (Tan 1985).

The Fisheries Development authority of Malaysia (LKIM), a government statutory body formed in 1971, with the twin objectives of upgrading the socioeconomic status of fishermen and developing the fisheries industry, is also involved in sea bass culture, especially in setting up commercial culture projects involving the participation of local fishermen (Khalil 1985).

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In addition to the government bodies, some universities in Malaysia also carry out activities relating to sea bass culture, especially disease studies.

Natural Seed Supply

Initially, the sea bass seed supply for culture in cages and ponds was from the natural fry ground. There is one such area in Peninsular Malaysia, in the state of Kedah. This is an area of abandoned rice fields along the coast. The seeds are washed into these fields during high tide and are trapped in pools when the tide subsides. They are then collected by the villagers and sold to the main collector who gathers the seeds and sells them to the sea bass culturists.

As sea bass culture expanded in the late 1970s the supply of seeds from this source was found to be inadequate and inconsistent.

Hatchery Seed Propagation

The earlier success in sea bass propagation in Thailand has stimulated research in this field in Malaysia. In July 1982, with the expansion of research hatchery facilities at Glugor, the first hatchery production of sea bass fry in Malaysia was achieved based on broodstock caught from the water off Telok Air Tawar, Penang (Ali et al. 1985).

Fry raised from this successful breeding venture have now been reared to maturity in net cages in Kuala Setiu Lagoon, Trengganu. Since July 1985, after the mature fish were transferred to the spawning tanks, built at Finfish Hatchery of the Fisheries Department in Tanjung Demong, Trengganu, several spawnings have been obtained from this broodstock. The spawning of sea bass under controlled environment of the hatchery has been so successful that several millions of fertilised eggs and hatchlings have been obtained per month, with the surplus being supplied to private hatcheries at nominal cost (Ong 1986).

The Fisheries Development Authority of Malaysia also has one hatchery project whose main function is to supply sea bass seed to its cage culture projects throughout the country.

Grow-Out

In Malaysia, sea bass culture is normally carried out alongside other marine/brackishwater finfish such as grouper *(Epinephalus tauvina)* and snapper *(Lutianus johni, L. argentimaculatus)* in floating net cages. These cages are mainly located in the states of Johor, Penang, Selangor, Kedah and Perak but sea bass culture is slowly gaining popularity in other parts of the country.

The estimated sea bass production from cages recorded in the Annual Fisheries Statistics 1982 and 1983 are 144.9 t and 223 t respectively. Currently, the total sea bass production from cages is about 400 t a year, which is about half of the total finfish production from cages in Malaysia (Tengku Dato' Ubaidillah 1985).

Sea bass culture in Malaysia is operated by group or family-unit systems as previously practised in the cage culture of grouper. By late 1985 the LKIM, using the family-unit system, has implemented 10 cage culture schemes which include sea bass culture involving 225 fishermen and the construction of 2862 cages in Peninsular Malaysia. Each fisherman is given a fixed loan in the form of materials for building 12–16 cages and other inputs such as fish fry and trash fish (Khalil 1985).

Besides the LKIM schemes, there are private operators many of whom were initially given subsidies in terms of materials for building rafts and cages for fry by the Department of Fisheries. Since then many of these operators have expanded on their own.

Currently, the size of seeds used to begin the cage culture in Malaysia is about 75 mm. At present, the seeds are mostly imported, either directly from Thailand or through Singapore, and the cost of each seed is M$1.30–1.50.

The fish are fed twice a day ad libitum with trash fish which costs about M$0.20–0.50/kg, depending on location. They are reared about 5–9 months to reach marketable size of about 500 g and are sold live to seafood restaurants and hotels at M$6.50–8.00 depending on season.

Although there are few ponds used for sea bass culture in the states of Kedah, Johor and Penang in Peninsular Malaysia, this practice has not expanded as much as the cage culture practice (Ong 1983). The estimated sea bass production from ponds recorded in the Annual Fisheries Statistics actually showed a decline in production from 89.6 t in 1982 to 4.3 t in 1983.

Problems and Constraints

Because sea bass culture is new to Malaysia, a number of problems must be solved. Although these problems and constraints may impede the development of culture at the present time, it is hoped that some of them will be overcome in the near future. Listed below are some of the problems: a) although hatchling production and larval rearing have been achieved by the Fisheries Department, the private sector in Malaysia has not set up commercial hatcheries as in Thailand; b) the nursing of fry to fingerling stage is still not well established; c) the nutritional requirements of the various stages of sea bass are not fully understood; d) there is a need to develop a cost-effective feed to reduce the cost of production; and e) larval mortalities still often occur, without the cause(s) being definitely identified.

Future Program

The launching of the National Agriculture Policy in 1984 has given aquaculture development high priority, and sea bass culture has been chosen as one of the projects that will be stepped up. The Malaysian Government envisages the establishment of 330 000 m^2 (or 8250 units) of marine floating cages for the culture of sea bass which are expected to increase production to 4000 t by the year 2000.

Towards this end the government has formulated strategies and programs which envisage a concerted effort by both the public and private sector. The most significant government inputs to achieve the stated target would be the provision of supporting institutional services such as research, extension, training, resource management, marketing service and fiscal incentives (Tengku Ubaidillah 1986).

Acknowledgments

I wish to express my gratitude to the Australian Centre for International Agricultural Research (ACIAR) for the opportunity to participate in the workshop. I would also like to thank the Director-General of Fisheries, Y.M. Tengku Dato' Ubaidillah bin Abdul Kadir, for permission to present this paper, the Director of Research of the Fisheries Research Institute, Encik Shaari bin Sam Abdul Latiff, for his encouragement, and Mr Ong Kah Sin, Ms Choo Poh Sze for their advice in the preparation of this paper.

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Review of FAO Research on *Lates calcarifer*

Pinij Kungvankij*

The Food and Agriculture Organisation (FAO) has identified sea farming, especially sea bass culture, as one of the areas to develop the aquaculture industry, and has expressed its desire to fund a major thrust in this area. Since sea bass fetches a high price, it is very attractive for commercial- or small-scale culture operations meant to increase the income of small-scale farmers or fishermen. FAO's role has been to conduct and coordinate research and disseminate information to industry to enhance development of commercial sea bass culture.

Many other research projects (including those of the Network of Aquaculture Centres in Asia, (NACA), are involved in sea bass culture development. Also, a training course on sea bass spawning and larval rearing was organised by the Department of Fisheries of Thailand and FAO/UNDP South China Sea Fisheries Development Program (SCSP) in Thailand in 1982.

Research Activities

The overall research approach was subdivided into two parts: experimental and developmental. Experimental is geared toward adopting a multidisciplinary approach, involving teamwork by specialists in the disciplines concerned. This includes gonadal maturation and reproduction, hatchery and nursery, grow-out, and economic and biological evaluation so as to develop or package a technology which can be relatively reliable for immediate application by the farmers in the region. Positive economic and biological evaluation from the experiments will lead to development, and the demonstration of a pilot farm which will eventually lead to commercial rearing.

Experimental

While the sea bass have been extensively cultivated in ponds and cages in many countries in the region, seed supply and high feed costs have been serious constraints to the expansion of the industry.

Intensive research is needed to develop the necessary broodstock development techniques and hatchery technologies for sea bass through refinement and standardisation of various spawning and larval-rearing techniques established elsewhere. Studies directed toward establishing standardisation of grow-out technology in the appropriate culture system would expedite the expansion of fish farming in many countries in the region.

The experimental phase is mainly conducted by NACA.

Development of Broodstock

The research is intended to develop a standardised technique for the establishment of broodstocks by studying the effect of high protein diet and feeding manipulation on gonadal development and the optimal stocking rate of broodstock.

The techniques currently used for induced spawning need further refinement and standardisation. Studies on the hormonal manipulation in spawning include comparative effects of different hormones, standardisation of the dosage injection interval, and quantity of fluid per injection. Also, studies are being done on environmental manipulation in induced spawning, which attempt to determine the environmental factors affecting gonadal maturation and the application of environmental parameters to stimulate natural spawning.

The research studies on development and refinement of larval rearing techniques are geared toward refining and standardising techniques in stocking, feeding and water management. The economic advantage of natural feeds versus artificial pellet feeds also requires testing and assessment.

Pond Culture of Sea Bass

Sea bass has been fairly extensively cultivated in ponds and cages in many Southeast Asian countries. Although cage culture technology of this species is being developed in Hong Kong, Singapore, Malaysia and Thailand, grow-out culture techniques in ponds have not yet been standardised.

The need to consider application of intensive farming technology for raising carnivorous fish becomes obvious, especially since land cost is increasing and cheap feeds are limited. Intensive farming means

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higher inputs in terms of cost of seeds, feeds, energy and operational maintenance. However, overall production costs may be reduced.

Experiments are therefore designed to verify economic benefits by application of high-density farming technology, e.g.: (a) optimal stocking density in relation to dissolved oxygen level and water temperature; (b) determination of nutritional requirements; (c) growth performance of formulated feeds; (d) standardisation of operation and management procedures; (e) increasing pond yields through polyculture with forage fish; and (f) economic evaluation of high-input farming systems for sea bass production.

Furthermore, the studies also evaluated the growth performance of hatchery-bred fry and wild-caught fry to determine appropriateness in using hatchery-bred fry for sea bass farming.

Development

Most country projects are under the technical assistance of FAO/UNDP, which implemented the development program on sea bass farming. Current projects are: The *pilot fish culture in floating cages* under FAO has been established in many Southeast Asian countries such as Malaysia, Indonesia, Thailand etc. since 1976. As part of its program to improve the standard of living, the project encourages aquaculture practices among the fishermen.

FAO also provides technical assistance on sea bass *hatchery development* in Malaysia, and expects to have another project in Indonesia.

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Culture — Cage

Optimum Stocking Density of Sea Bass *(Lates calcarifer)* Cultured in Cages

Wichien Sakaras*

THE sea bass *(Lates calcarifer)* is of great commercial value in Southeast Asia. In Thailand, induced spawning of sea bass has been successfully achieved and sea bass seed is readily available. In Thailand, sea bass cage culture is mainly conducted in the southern part of the country with stocking densities of 12 fish/m^2 (Department of Fisheries 1976). Culture has now been expanded to the central part of Thailand. The marketable size of sea bass is approximately 500–800 g. The stocking rate of 12 fish/m^2 was considered low for cage culture, so the Rayong Brackishwater Fisheries Station conducted research, during 1980 and 1983, to explore the possibility of increasing stocking rates. Results of the study indicated that sea bass could be reared in floating net cages with stocking rates as high as 100 fish/m^2 (Sakaras and Sukbanteang 1980, 1981, 1982, 1983). Other species can also be reared in cages at higher stocking rates. Yellowtail culture in Japan shows optimum stocking density in cages to be 80–200 fish/m^3 of 5–10-cm fish (Fujiya 1976). For striped bass (*Morone saxatilis*) fingerlings (average weight 131–145 g) cultured in cages in brackish water, stocking rates were as high as 300 fish/m^3 (Powell 1972). For estuary grouper (*Epinephelus salmoides*), the optimum stocking density was 156 fish/m^3 for culturing in cage by using artificial hides (Teng and Chua 1979).

The present study was conducted to determine the optimum stocking rate of sea bass for cage culture as well as size of seed fish to be stocked.

Materials and Methods

Experimental Fish

The fish were spawned at Rayong Brackishwater Fisheries Station. Sea bass larvae were nursed in four 6–t cement ponds for 124 days (5 May–5 September 1983). The fish were fed zooplankton (*Brachionus plicatilis* and *Artemia salina*) during the first couple of months, then they were fed ground fish flesh.

Culture Cages

The cages measured 1 × 1 × 1.5 m and were made of polyethylene netting of 2.5 cm mesh size. The rectangular frame of the cages was 0.75-inch steel pipe. The cages were suspended from three bamboo rafts. The volume of each cage was 1.3 m^3. The cages were suspended near the shore of Samed Island in Rayong Province.

Experimental Design

The randomised complete-block design was used for the experiment. Details of the experimental design are shown in Table 1. Five stocking densities and three size groups (block) of initial fish were studied. In block I, the size of initial fish ranged from 10.1 to 12.5 cm in total length, in block II from 12.6 to 15.0, and in block III 15.1 to 17.5 cm. These size groups are commonly used in sea bass cage culture in Thailand.

Feed and Feeding

Carrangids (*Caranx leptolepis*) were chopped into small pieces and fed to satiation to the fish twice a day. Satiation is said to be reached when excess food is not taken within 2–5 min. The total weight of food taken by the fish in each case was recorded daily.

Data Analysis

Data collected were analysed for the following: (1) mean fish weight: the average weight of fish at *t* days; (2) weight gain/cage: $W_t - W_0$ (kg) where. W_t = total weight of fish that survived in a net cage at the end of experiment; W_0 = total weight of initial fish in a net cage; (3) survival rate: $N_t/N_0 \times 100$ (%) where, N_t = total number of fish that survived in a net cage at the end of the experiment; N_0 = initial number of fish in a net cage; (4) food conversion rate: wet weight of food eaten/wet weight gained by the fish; and (5) fish production: total weight of fish that survived in a net cage (kg).

Statistical Analysis of the Data

Analysis of variance was used to test the effect of stocking density on various growth parameters. Duncan's new multiple range test ($p \leq 0.05$) was employed to compare the significance of the means of

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Table 1. Experimental design, initial stocking densities, initial biomass and size of fish stocked.

	1	2	3	4	5
Block I					
Initial stocking density of fish/cage*	100	150	200	250	300
Average size of initial fish in total length (cm) ± SD	11.8±0.7	11.8±0.7	11.8±0.7	1.8±0.7	11.8±0.7
Average size of initial fish in weight (g) ± SD	22.1±5.1	22.1±5.1	22.1±5.1	22.1±5.1	22.1±5.1
Initial biomass stocked (kg/cage)	2.2	3.3	4.4	5.5	6.6
Block II					
Average size of initial fish in total length (cm) ± SD	13.5±0.6	13.5±0.6	13.5±0.6	13.5±0.6	13.5±0.6
Average size of initial fish in weight (g) ± SD	32.9±4.5	32.9±4.5	32.9±4.5	32.9±4.5	32.9±4.5
Initial biomass stocked (kg/cage)	3.3	4.9	6.6	8.2	9.9
Block III					
Average size of initial fish in total length (cm) ± SD	16.4±1.1	16.4±1.1	16.4±1.1	16.4±1.1	16.4±1.1
Average size of initial fish in weight (g) ± SD	58.0±14.3	58.0±14.3	58.0±14.3	58.0±14.3	58.0±14.3
Initial biomass stocked (kg/cage)	5.8	8.7	11.6	14.5	17.4

* Volume of the net cage submerged in water = 1.3 m^3 and surface area of the net cage = 1 m^2.

the various growth parameters among the stocking densities test (Steel and Torrie 1960).

Environmental Conditions

Water samples were collected at fortnightly intervals inside and outside the cages for determination of some basic environmental conditions during the period of the experiment. Data were recorded on salinity, pH, dissolved oxygen, and air and water temperature.

Results

Mean Fish Weight

The mean fish weights at stocking densities of 100, 150, 200, 250 and 300 fish/cage were 573.32, 569.92, 551.39, 527.16 and 505.41 g respectively (Table 2). There were no significant differences ($p \leq 0.05$) among the five stocking densities. The mean fish weight at stocking density of 300 fish/cage was significantly lower ($p \leq 0.05$) than the mean fish weight at 100 and 150 fish/cage but not significantly different ($p \geq 0.05$) from that of the 200 and 250 fish/cage (Table 3). Statistical analysis showed that stocking larger size of seed fish gave higher mean weight compared with smaller seed fish.

Weight Gain Per Cage

Average weight gain per cage of the fish at stocking densities of 100, 150, 200, 250 and 300 fish/cage were .49.83, 77.52, 101.24, 115.81 and 137.40 kg respectively. Differences among weight gain per cage per stocking density were statistically significant ($p \leq 0.01$; Table 3).

Survival Rate

Survival rates of the fish at each stocking density were not statistically significant ($p \geq 0.05$). The size group of seed fish had no effect on survival rate. The average survival rates for stocking densities of 100, 150, 200, 250 and 300 fish/cage were 93.3, 97.1, 99.3, 94.9 and 98.1% respectively.

Table 2. Mean fish weights of sea bass cultured in floating net cages in 210 days at five stocking densities by using three different groups of initial fish.

No. days	Mean fish weight (g) at stocking density of				
	100	150	200	250	300
30	119.7	115.6	116.7	117.7	117.8
60	222.7	218.4	208.6	212.4	208.1
90	309.0	306.4	294.4	293.1	285.1
120	380.3	361.2	368.0	353.0	345.7
150	448.0	420.5	418.0	410.9	379.4
180	523.4	495.8	463.3	449.9	436.5
210	573.3	569.9	551.4	527.2	505.4

Table 3. Results of sea bass rearing in five different stocking densities at 210 days and comparison of mean by Duncan's new multiple range test ($p \leq 0.05$).

	I	II	III	IV	V
Initial (average from 3 blocks)					
No. of individuals per cage	100	150	200	250	300
Mean individual weight of fish (g)	37.7	37.7	37.7	37.7	37.7
Total weight of fish per cage (kg)	3.8	5.7	7.5	9.4	11.3
Standard deviation of individual weight	18.4	18.4	18.4	18.4	18.4
Final results (average from 3 blocks)					
Survival rate (%)	93.3[a]	97.1[a]	99.3[a]	94.9[a]	98.1[a]
Mean individual weight of fish (g)	573.3[a]	569.9[a]	551.4[ab]	527.2[ab]	505.4[b]
Standard deviation of individual weight	44.5	60.1	48.6	30.7	47.0
Total weight of fish per cage (kg)	53.6[a]	83.2[b]	109.5[c]	125.3[d]	148.7[e]
Total weight increase per cage (kg)	49.8[a]	77.5[b]	101.2[c]	115.8[d]	137.4[e]
Food conversion rate	7.8[c]	5.8[b]	5.4[b]	5.0[ab]	4.6[a]

a, b, c, d, e = Values designated by the same letter were not significantly different ($P \geq 0.05$)

Food Conversion Rate

Food conversion rate decreased with stocking density. They were 7.8, 5.8, 5.4, 5.0 and 4.6 from the stocking densities of 100, 150, 200 and 300 fish/cage respectively. Food conversion rates of fish at a stocking density of 300 fish/cage were best and significantly lower ($p \leq 0.05$) than the stocking density of 200, 150 and 100 fish/cage (Table 3). Food conversion rates of the fish at a stocking density of 300 and 250 fish/cage were not statistically different ($p \geq 0.05$). The results showed that fish at a stocking density of 100 fish/cage gave the highest food conversion rate which was significantly higher than the other stocking ($p \leq 0.05$; Table 3). The size of seed fish had no effect on food conversion rate.

Fish Production

After 210 days, fish production per cage increased steadily with increase in stocking density. Fish production from various stocking densities was 53.60, 83.17, 109.50, 125.23 and 148.70 kg/cage, respectively from stocking density of 100, 150, 200, 250 and 300 fish/cage. The increase in fish production was statistically significant ($p \leq 0.05$) at every stocking density. The increase in fish production at a stocking density of 300 fish/cage was 277% over that of 100 fish/cage and 119% over that of 250 fish/cage.

Environmental Conditions

During the period of study, air temperature of the culture site varied from 27.3 to 32.5°C. Outside the cages, the water temperature ranged from 27.0 to 30.5°C, salinity from 32.0 to 34.0‰, dissolved oxygen content from 6.2 to 7.3 ppm, and pH from 7.2 to 8.4. Inside the cages, water temperature and salinity were the same as outside, dissolved oxygen ranged from 5.80 to 7.00 ppm, and pH from 7.20 to 8.40. The variations of these physical and chemical parameters of the water inside and outside the cages were not statistically significant ($p \geq 0.05$). The mean water temperature during the experimental trial was 28.5°C, being the winter season.

Discussion

The results of this experiment showed that mean fish weight of sea bass decreased with increase in stocking density. Teng and Chua (1978) and Trzebiatowski et al. (1981) also reported similar results with estuary grouper (*Epinephelus salmoides*) and rainbow trout (*Salmo gairdneri*). Fish production and total weight per cage increased with stocking density and fish production of 300 fish/cage was significantly higher than lower stocking densities. Mean fish weight of 300 fish/cage was 505.4 g and the fish production was 148.7 kg. The mean fish weight and production at 100 fish/cage was 573.3 g, and 53.6 kg, respectively. The difference of mean fish weight between the stocking density of 100 fish/cage and 300 fish/cage was 67.9 g. The difference of fish production between the stocking density of 300 and 100 fish/cage was 95.1 kg. The difference of mean fish weight between these two stocking densities was small but in fish production high. In Thailand, marketable sizes of sea bass are 500–800 g by body weight, which indicates that the fish stocked at a density of 300 fish/cage grew to marketable size. The results showed that the food conversion rate of fish at 300 fish/cage was significantly lower than 100–200 fish/cage. Summarising all parameters of this experiment, results indicated that fish stocked at 300 fish/cage (300 fish/m^2 or 230.8 fish/m^3) showed the highest production among all trials. Fish grew to a marketable size with a production rate of 148.7 kg, survival rate of 98.1% and food conversion rate of 4.6:1.

The results of this experiment showed that stocking larger size seed fish attained greater individual and total weight per cage than smaller ones. In terms of survival rate and food conversion rate, no significant differences could be ascertained among the three

groups. The results obtained showed that sea bass which range from 10–17 cm in length are suitable for culturing in the cages with grow-out at 6–7 months.

Previously sea bass cage culture experiments were carried out for 180 days, stocking 10–17 cm seed fish (Sakaras 1983). The length of this trial, 210 days, was due to slower growth for sea bass during the winter season.

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Cage Culture of Sea Bass *(Lates calcarifer)* in Indonesia

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SEA BASS (*Lates calcarifer*) has long been of interest to the aquaculturist, because of its good taste and relatively high market value. Although culture of sea bass has been practiced for many years, there was no large-scale commercial culture of this fish until 1974. The fry used for culture in the last decade are entirely dependent on the availability of fry from the wild which means the supply was very erratic.

The successful breeding of sea bass in captivity and the completion of its life cycle in early 1970 assured sufficient and consistent supply of fry in the sea bass culture industry (Wongsomnuk 1971).

Sea bass culture enterprises could become one of the most dynamic and most profitable segments of the brackishwater and marine fish farming industry in Southeast Asian countries. It is a desirable fish with good fresh texture and taste, and a high market value and demand. It can be reared both in freshwater, brackishwater and seawater conditions. In the past 5 years, over 10 000 farmers engaged in cage culture of sea bass and over 20 000 ha of land have been established in the region for intensive pond production of the species.

Culture Techniques

Cannibalism is one of the most serious problems in sea bass culture. High mortality is often encountered when uneven sizes of fish are stocked. This has occurred mostly where the fish are very young (1–20 cm in length, the first 2 months of culture). To minimise this problem, culture of sea bass should be approached in two phases, i.e. the nursery phase and the grow-out phase.

Nursery Phase

The main purpose of the nursery phase is to culture the fry from hatchery (1–2.5 cm in size) to juvenile (8–10 cm). Beyond the nursing period, the juveniles can be graded into different size groups and stocked in separate grow-out ponds.

Grow-Out

The grow-out phase involves the rearing of the sea bass from juvenile to marketable size, which varies from country to country. The normally accepted marketable size of sea bass in the Southeast Asian Region is 700–1200 g while in the Philippines, marketable size is 300–400 g. The culture period in grow-out phase also varies from 3–4 months (to produce 300–400 g) to 8–12 months.

Cage Culture

Cage culture of sea bass is quite well developed in Thailand, Malaysia, Indonesia, Hong Kong and Singapore. The success of marine cage culture of sea bass and its economical viability have contributed significantly to large-scale development of this aquaculture system (Dhebtaranon 1976).

SUITABLE SITES

Criteria for selecting a suitable site for cage culture include:

(a) Protection from strong wind and waves The cage culture site should preferably be located in protected bays, lagoons, sheltered coves or inland sea.

(b) Water circulation The site should preferably be located in an area where influence of tidal fluctuation is not pronounced. Avoid installing cages where the current velocity is strong.

(c) Salinity The salinity range should be 13–30‰.

(d) Biofouling The site should be far from the area where biofoulers abound.

(e) Water quality The site should be far from sources of domestic, industrial and agricultural pollution and other environmental hazards.

DESIGN AND CONSTRUCTION

In general, square and rectangular cages varying from 20 to 100 m^3 are preferable because they are easy to construct, manage and maintain. Sea bass cages usually are made of polyethylene netting with the mesh size ranging from 2 to 8 cm. The choice of mesh size depends on the size of the fish: 0.5 cm for 1–2-cm fish; 1 cm for 5–10-cm fish; 2 cm for 20–30-cm fish; and 4 cm for >25-cm fish.

There are two types of cages used in sea bass culture:

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Floating cages are attached to wooden, GI pipe or bamboo frames. The cage is kept afloat by floating material such as metal, plastic, styrofoam drum or bamboo. The shape of the cage is maintained with the use of concrete weights attached to the corners of the cage bottom. The most manageable size for a floating cage is 50 m^3 (5 × 5 × 2 m). This cage dimension is easy to change when clogged with fouling organisms.

Stationary cages are fastened to the bamboo or wooden poles installed at its four corners. These cages are popularly used in shallow bays since they are easy to install.

MANAGEMENT TECHNIQUES

Prior to stocking sea bass juveniles in cages, fish should be acclimatised to the ambient temperature and salinity prevailing in the cages. The fish should be graded into several size groups and stocked in separate cages. The stocking time should be in the early morning (0600–0800 hours) or late in the evening (2000–2200 hours) when the temperature is cooler.

Stocking density in cages is usually between 40–50 fish/m^3. Two to three months thereafter, when the fish have grown to between 150 and 200 g, the stocking density should be reduced to 10–20 fish/m^3. Table 1 shows the growth of sea bass under varying densities in cages. One should have spare cages as these are necessary for transfer of stock and to effect immediate change of net in the previously stocked cage, once it has become clogged with fouling organisms. Changing cages allows for grading and controlling stock density.

Table 1. Monthly growth (in grams) of sea bass at different stocking densities in cages (after Sakaras 1982).

Culture period (*months*)	Stocking density		
	16/m^2	24/m^2	32/m^2
0	67.8	67.8	67.8
1	132.3	137.5	139.2
2	225.2	229.1	225.5
3	262.9	267.5	264.1
4	326.2	332.0	311.5
5	381.1	384.9	358.8
6	498.6	487.1	455.4

FEEDS AND FEEDING

Feed is the major constraint confronting the sea bass culture industry. At present, trash fish are the only known feed stuff used in sea bass culture. Chopped trash fish are given twice daily in the morning at 0800 hours and afternoon at 1700 hours at the overall rate of 10% of total biomass in the first 2 months of culture. After 2 months, feeding is reduced to once daily and given in the afternoon at the rate of 5% of the total biomass. Food should be given only when the fish swim near the surface to eat.

Since the supply of trash fish is insufficient and expensive in some countries, its use is minimised by mixing rice bran or broken rice (30%) to the trash fish (70%). However, even with these cost cutting measures, feed cost remains quite high.

A very recent development on improving the dietary intake of sea bass is the introduction of moist feed. So far, the use is still in an experimental stage. The feed composition recommended is: fish meal, 35%; rice bran, 20; soybean meal 15; corn meal, 10; leaf meal, 3; squid oil (or fish oil), 7; starch, 8; vitamin mix, 2.

FISH CAGE MANAGEMENT

Regular observation of cages is required. Since fish cages are immersed, they are vulnerable to destruction by aquatic animals such as crabs, otters, etc. If damaged, they should be repaired immediately or replaced.

In addition to biofouling, the net walls of cages are subjected to siltation and clogging. Biofouling is unavoidable since the net walls usually represent a convenient surface for attachment by organisms such as amphipods, polychaetes, barnacles, molluscan spat, etc. These could lead to clogging and reduce exchange of water and may result in unnecessary stress to the cultured fish due to low oxygen and accumulation of wastes. Feeding and growth would likewise be affected.

Mechanical cleaning of fouled nets is still the most efficient and cheapest method. In areas where fouling organisms are abundant, rotational usage of net cages is highly recommended.

Pond Culture

Although methods of pond culture of sea bass have been practiced for over 20 years in Southeast Asia and Australia, not much has been done on the commercial scale (SCFP 1982). At present, culture of sea bass in brackishwater ponds has been identified in some countries as having tremendous market potential and high profitability. These, however, can be achieved if conditions are met such as adequate fry supply, availability of suitable sites and properly designed fish farms. Supply of fry from the wild is very limited. As with cage culture, it is one of the constraints in the intensification of sea bass culture in ponds. However, with the success in artificial propagation of sea bass, fry supply may largely come from this source in the future. A comparison of hatchery-bred and wild fry cultured in ponds did not show very significant differences in growth rates (Table 2).

There are two culture systems employed in pond culture of sea bass. The *monoculture* system has a serious disadvantage, since it is entirely dependent on supplementary feeding. The use of supplementary feed reduces profit to a minimum, especially where the supply of fresh fish is limited and expensive.

Table 2. Growth performance of sea bass (*Lates calcarifer*) culture in ponds between wild fry and hatchery-bred fry at stocking density of $3/m^2$.

	Wild		Hatchery-bred	
	BL (*cm*)	BW (*g*)	BL (*cm*)	BW (*g*)
Stocking	10.5	40.4	5.2	5
1st month	13.0	88.9	7.6	12.0
2nd month	16.4	204.2	10.6	26.02
3rd month	20.9	276.3	15.2	118.1
4th month	23.4	326.5	19.5	220.9
5th month	24.1	385.2	21.8	280.6
6th month	28.2	453.5	23.2	349.6

Polyculture shows great promise in reducing, if not totally eliminating, dependence on trash fish as a food source. The method is achieved by simply incorporating a species of forage fish with the main species in the pond. The choice of forage fish will depend on its ability to reproduce continuously in quantities sufficient to sustain the growth of sea bass throughout the culture period. The forage fish must be a species that could make use of natural food produced in the pond and which does not compete with the main species in terms of feeding habit (e.g. *Oreochromis mossambicus, Oreochromis niloticus,* etc.).

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Culture Trials for Sea Bass *(Lates calcarifer)* in Floating Net Cages

Budiono Martosudarmo*

Sea bass (*Lates calcarifer*) have long been known as the by-product of brackishwater harvest in Indonesia. Its occurrence in the brackishwater ponds is as an unwanted species along with the other fish like tilapia, mullet, etc. This estuarine fish is actually a potential predator to the milkfish and shrimp culture industry. The young fish enters the pond through the incoming water during high tide. Among those unwanted species, however, the sea bass gives the best price in the market and accordingly has a good demand.

With improving technology of brackishwater culture, the eradication of pests and predators in the pond becomes more intensive and brings about a reduction of sea bass stocks in the market. Therefore, an attempt has been made to cultivate sea bass in floating net confinement and the results are reported here.

Materials and Methods

A 3 × 3 × 3 m polyethylene net cage of 2-cm mesh size is used in the culture trial. The net cage is attached to a bamboo frame kept floating by 60-l plastic containers (Fig. 1). The net cage is divided into four equal compartments using the same netting material, so that each compartment has a volume of 1.5 × 1.5 × 3 m or 6.75 m^3. Young sea bass obtained from fishermen collected from brackishwater ponds and canals are used as culture material. Several days are needed to collect enough fish and they are held temporarily in a small pond before being moved to the culture site.

After about 2 hours in oxygen-inflated plastic bags, the fish is conditioned in a 1-t fibreglass tank for 3 days and then visually selected as far as possible in even sizes. Only fish in good condition are taken for stockings.

Due to the limited number of fish obtained, only three compartments were used in the culture trials. One hundred and seven specimens ranging from 180 to 600 g were selected and distributed to the three compartments at 43, 41 and 23 fish/compartment. The stocking biomass estimated for the compartments was 10.5, 10.7 and 10.0 kg and extrapolated to simulate a stocking rate of 6.7, 6.1 and 3.4 fish/m^3, respectively.

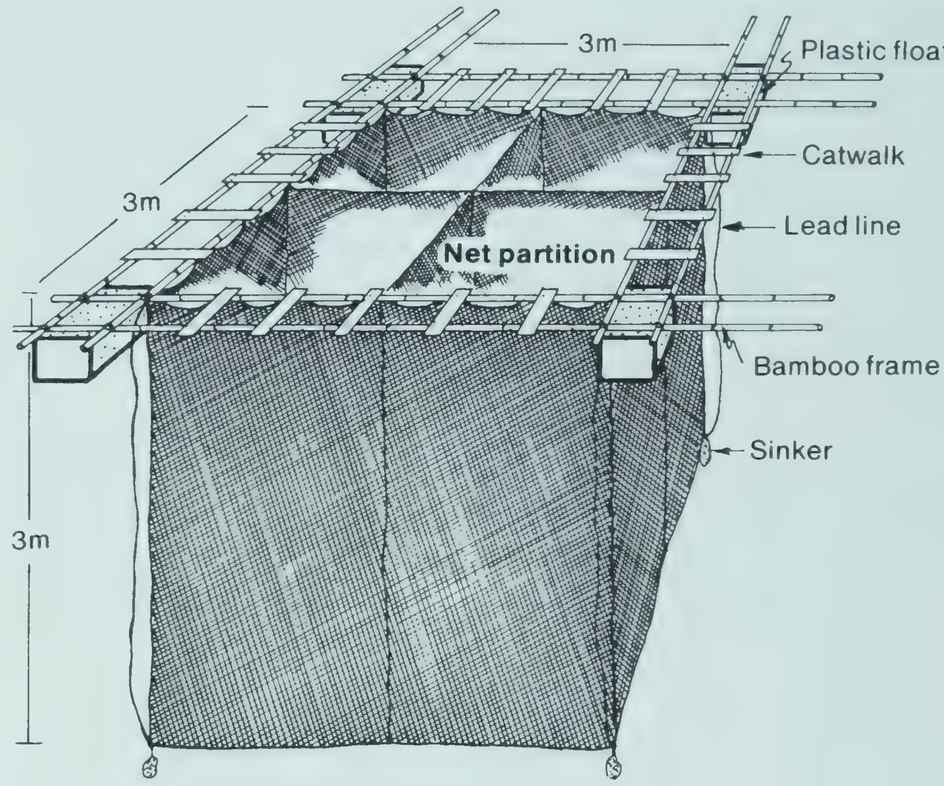

Fig. 1. Floating net cage.

Feed in the form of chopped fresh trash fish was given to the cultured fish twice a day, in the morning at 0800 hours and in the afternoon at 1500 hours. The amount of feed given was about 8% of the total biomass of the stocked fish.

During the culture period of 5 months, changing of net cage is conducted twice to maintain a good water exchange in the cage and water parameters are measured monthly to monitor its quality.

Results and Discussion

The size and weight of fish stocked and harvested, amount of feed given and the weight increment gained during the 5-month culture period in the three compartments are presented in Table 1. The monthly water parameters were: pH 7.9–8.1; salinity 31–33‰, DO 4.7–6.3 ppm, temperature 29–30°C, and transparency 6.3–8.5 m.

The stocking rate applied in the trial ranged from 23 to 43 fish/compartment or from 3.4 to 9.03 fish/m^3. This stocking is considered low compared to those recommended in Thailand using 23–30 juveniles with size ranging from 8 to 10 cm/m^2 in floating net cages (1 m long × 1 m wide × 1 m deep; Sirikul 1982). The low stocking density used in this case is mainly

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Table 1. Data on culture trial of sea bass grown for 5 months (152 days) in floating net cages.

	Compartment 1	Compartment 2	Compartment 3
Data of stocking	26.11.84	26.11.84	26.11.84
Stocking biomass (kg)	10.5	10.7	10.0
No. of stocking (fish)	43	41	23
Range of stocking size (cm)	23.0–29.0	23.8–30.0	29.5–36.0
Range of stocking weight (g)	180–320	195–400	310–600
Feed given (% of biomass)	8	8	8
(total in kg)	228.5	192.13	124.23
(average daily in kg)	1.5	1.26	0.81
Date of harvest	27.4.85	27.4.85	27.4.85
Survival (%)	100	100	100
Harvest biomass (kg)	37.8	36.0	25.1
Total weight increment (kg)	28.2	25.3	15.2
Av. daily weight increment (g)	4.3	4.1	4.3
Range of harvest size (cm)	32.0–42.0	33.4–44.0	41.0–48.0
Range of harvest weight (g)	500–1150	550–1210	920–1550
Feed Conversion Rate	8.1	7.6	8.2

due to the limited number and variety of fish available. The variety in fish size used in the culture of preying species tends to increase cannibalism, particularly when the feed given is not sufficient. In terms of stocking density as a comparison, Teng et al. (1977) reported a stocking density of 30–60 fish/m^2 is used for the groupers, *Epinephelus tauvina,* using fish 82–130 g in weight in a net cage of 1.83 × 2.13 × 1.52 m. With the addition of shelters inside the cage, the stocking density may be increased without any adverse effect on their growth (Teng and Chua 1979).

A feeding ration of about 8% of the total biomass gave an average daily weight increment of 4.3, 4.1 and 4.3 g in compartments 1, 2 and 3, suggesting a feed conversion rate of 8.1, 7.6 and 8.2 respectively. Looking at the rate of feed conversion in the trial, the amount of feed given seems to be excessive. In general, feed contributes a predominant input in the culture of preying species, therefore the amount of feed ought to be reduced in order to lower the cost of production.

This reduction is not likely to affect the growth of fish. In the work done by Chua and Teng (1982) on the estuary groupers *Epinephelus salmoides*, a food ration of 5–8% of body weight gave a more uniform size.

The good survival rate in the trial might be attributed to the low stocking density and good water quality.

Problems and Constraints

Unlike in freshwater fish culture, floating net cage culture for marine finfish is not common in Indonesia. Sea bass itself is also a new cultured species introduced to the farmers despite its popularity in the country. In promoting the culture of this species, problems and constraints encountered are: (a) *Availability of seed used for culture.* No marine finfish hatchery has yet been established and therefore fry/fingerlings have to be obtained from the wild. Since the collection of sea bass fry/fingerlings from the wild is unfamiliar to the fishermen, the availability of seed is uncertain and unpredictable. As well, the fishing gear used to collect the fish tends to cause high mortality; (b) *Availability and price of feed.* The feed used in sea bass culture, natural and formulated will depend on the trash fish available. Trash fish is also eaten by the local population, so it can also be too expensive for use as feed; (c) *Marketing of the products.* The high cost of trash fish as the main source of feed undoubtedly leads to an increase in the cost of production and consequently will reduce the market for sea bass sold almost entirely as iced fish.

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Sea Bass (*Lates calcarifer*) Research in the Seafarming Development Project in Indonesia

Banchong Tiensongrusmee*

INDONESIA has 5.8 million km^2 of marine coastal waters. The area has natural stocks of fish, cockle, mussel, oyster and seaweeds that artisanal fishermen can enjoy exploiting for their living. At present the resources are diminishing at a drastic rate as a result of heavy fishing pressure. The declining resources affect the livelihood of small-scale fishing families and rural communities. This can cause serious socioeconomic problems to the coastal communities.

One of the Fisheries Department policies in line with the REPELITA IV is to increase fisheries production through commercial and non-commercial programs. The former is directed towards increase in production through large-scale operations, whereas the latter is directed to the improvement of production of the low-income group. Seafarming is one means by which the coastal waters can be more effectively exploited and offers considerable development potential in this direction. Culture of marine finfish, cockle, mussel, oyster, and seaweeds is being developed for ultimate commercial aquaculture industries.

Potential Area for Finfish Culture Development

The potential areas suitable for finfish culture in floating netcages are (1) Batam Island; (2) Bintan Island in Riau (300 ha); (3) Bangka Island in South Sumatra (200 ha); (4) Teluk Hurun, Teluk Lampung in Lampung (800 ha); (5) Banten Bay in West Java (400 ha); (6) Gili Genteng Bay Madura; (7) Grajagan Banyuwangi in East Java (300 ha); (8) Pejarakan in Bali (50 ha); (9) Ekas Bay, Lombok in West Nusatenggara (200 ha); (10) Ujung Pandang in South Sulawesi (200 ha); (11) Ambon in Maluku (200 ha); and (12) Sangihe Island in North Sulawesi (200 ha). The estimated total area suitable for marine finfish in floating netcages is about 2900 ha.

Past and Current Activities

The FAO/UNDP Seafarming Development Project started its operational phase in February 1983 and is expected to end in September 1987. The past and current activities of the project on sea bass can be reviewed as follows:

Culture Trials

During 1984–85, culture trials on sea bass in grow-out cages were designed to assess the biomass carrying capacity of the test site under Indonesian conditions. The results obtained will be used as a basis to design a package of technology which is one of the project activities. The results from the culture trials suggested that the environment at Teluk Hurun can support a biomass carrying capacity between 12 and 15 kg/m^3 of water volume at harvest with satisfactory daily weight increments (avg 4 g/day). The feed conversion ratios (determined by dividing total weight of 'trash' fish consumed by total fish weight gain) ranged from 7.6:1 to 8.4:1 (avg 7.8:1). Other data such as investment costs, operating costs, and fixed costs are also recorded. The results of the culture trials were reported by Chan et al. (1985), and also by Budiono Martosudarmo (these Proceedings).

The current culture trials are carried out to assess the attainable yield, optimum stocking density, growth rate and feed conversion ratios not only in grow-out phase, but also in nursery phases of fingerlings to juvenile size, from 5.0–7.5 cm, and juvenile to young sea bass size, from 7.5–10.0 cm, to test the economic feasibility of the packaged technology designed. The feed conversion ratio proposed in the package is 5:1 (or less), which can be done by improving the efficiency of the feed and the feeding program through more efficient production management practices. Self capture fresh fish for feed use is another alternative whenever its cost can be reduced substantially.

Compound Feed Development

In Indonesia, very small fish, commonly designated 'trash' fish, is utilised for human consumption. This aggravates the availability and raises the price of trash-fish in relation to its increased use as fish feed. The feed cost of the package is about 55% of the production cost. The cost can be reduced considerably

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if less expensive compound feeds are developed. With assistance of Prof. Dr. Samuel P. Meyers, Department of Food Science, Louisiana State University, Baton Rouge, Louisiana, USA, compound extruded moist feeds are now being developed at the project. It is anticipated that by utilising locally available feed ingredients such as seaweed (as a binder) and mussel meat (as an attractant), and ultimate reduction of the fish meal component, the cost of feed per kilogram should be notably reduced.

The developed moist feeds have been initially tested and are well accepted by the sea bass. Feed trials on growth and conversion rates are being carried out to determine if the compound feed either should ultimately replace 'trash' fish or allow 'trash' fish to be used sparingly during periods when it cannot be obtained at a reasonable price. Together with use of an appropriate feeding stimulant in the compound feed, and gradual reduction of the concentration of fish meal, the cost of feed to produce sea bass, as designed in the package, can in all likelihood be reduced from the present 55% to approximately 30–40% of the production cost.

Other improvements in feed manufacturing, ingredient substitution, and especially feeding practices should further contribute to this goal. The final objective is production of a least-cost dry diet acceptable to sea bass. All of the proposed feeding trials involve tests of diet acceptability, conversion rate, and feeding digestibility, fish growth, and final costs involved in production.

Fish Fry Survey

A major constraint to development of the finfish cage culture system for sea bass at present lies in the availability and price of fry and fingerlings used for culture purposes. At present, marine finfish hatcheries have not been established in Indonesia. The fry used for culture are now captured from the wild. In order to solve the problem, efforts have been made to explore new natural fry grounds. Information on availability of sea bass fingerlings and juveniles, as well as data on spawning ground and spawning season, were collected. The latter information is essential for artificial propagation of the sea bass which the project plans to implement in the near future.

It appeared that in the Maringgai area, the spawning season occurs between April and September. The fingerlings, ranging in size from about 2.5 to 5.0 cm, are found in estuarine, lagoon, and mangrove areas in October–November, whereas young sea bass, 5.0–15.0 cm, appear in February–March.

Formulation of a Packaged Technology

The culture practices introduced and tested in culture trials at pilot farms will be put into a package for the smallholder program. The package is designed with a target gain in monetary value based on a 1-year investment cycle. The annual net profit, divided by 12 months, would give an acceptable monthly net income to the cage operator and his family. The income is considered as being able to meet the planned national average income of around Rp 40 000/month/family. The package will provide information on required culture facilities, culture methods and techniques, and operation instructions.

The package uses a one floating net four-cage production with a unit cage size of $3 \times 3 \times 3$ m or $27 m^3$, or a total of $108\ m^3$ of impounded water. A grow-out operation starting with 150 g fingerling size, and using an average daily weight increment of 4 g/day and stocking rate 20 fish/m^3, could anticipate the following annual production performance:

$108\ m^3 \times 20$ fish/$m^3 \times 0.84$ kg/fish = 1814.4 kg/crop/6 month = 3628.9 kg/crop/yr

Live fish ex-farm price is proposed at Rp 3000 per kg

The gross revenue (Rp 3000 = 3628 kg) = Rp 10 844 000

The annual production cost = Rp 9 000 000

The farmer will have net income/yr = Rp 1 844 000 or Rp 153 666/month.

The package will be used as a manual and operational guideline for the Village Unit Co-operative Cage Culture Development Program.

Development of Postharvest System

With a view to maximising or insuring an optimum farmgate value for the product, as well as to sustain production costs at a beneficial level to the producer, the postharvest system is being studied and shall be established. Such establishment is not only attracting new entries, but also makes the development beneficial.

The products from cage culture operation have an advantage in their freshness, and can be delivered to the consumers alive in a constant supply. Such advantages give the farmed product a better price when compared with products from capture fisheries which are sold as iced fish. As proposed in the package, the ex-farm live fish should fetch at least Rp 3000/kg which is now offered by live fish brokers in Jakarta for live sea bass ranging between 800 and 1000 g in size. Live fish markets are now established among the groups that have a connection with restaurants in Jakarta, Surabaya, the Riau for domestic consumption and also for export to Singapore and Hong Kong for international markets.

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Production Techniques for Sea Bass *(Lates calcarifer)* Fingerlings in the Philippines

Romeo D. Fortes*

In a trial in Iloilo, Philippines, at the Bureau of Fisheries and Aquatic Resources (BFAR), in collaboration with the Aquaculture Department of Southeast Asian Fisheries Development Center (SEAFDEC-AQD), about 90 000 fry of sea bass were stocked in a pond and mortality of about 98% was experienced (Dimaano pers. comm.). The above experience shows that despite the success of the mass production of sea bass fry, fingerling production needs further investigations if culture fishery for sea bass is to succeed.

Techniques and experience in other countries that succeeded in producing sea bass fingerlings and other related species need to be studied in order that these can be modified, refined and simplified for adoption by sea bass fish farmers. In Thailand, for example, the success of sea bass fingerling production depends on the various food items that are appropriate for certain developmental stages of the larvae. Sea bass larvae are supplied with *Chlorella* and rotifer from day 3 to day 8. Between day 6 and 8 *Artemia* nauplii are added; from day 8–15, only *Artemia* is given and from day 16–25 the fry are fed with *Artemia* and *Moina* and/or *Daphnia*. *Acetes* or minced fish is introduced starting from day 24 until day 30. After day 30 the larvae completely metamorphosed into fry and are fed *Acetes* and/or minced fish until the fingerling stage (Maneewongsa and Tattanon 1982a,b).

Tattanon and Maneewongsa (1982a,b) described the management of the nursery tank for sea bass as follows: the sea bass larvae are transferred to the nursery tank when they are ready to feed (3 days old). In the nursery tank, green water is maintained mainly for the food of the rotifer, *Brachionus plicatilis*. This is done until the 14th day but *Artemia* is added on the 10th day. During this time water is replenished daily at the rate of 10–20%. From the 14th to the 25th day, feeding with *Artemia* is continued; *Daphnia* is fed beginning on day 20 and 50% of water is changed each day. From day 25–30 *Daphnia* and trash fish and/or *Acetes* are fed to the fry and 80% of the water in the nursery tanks is changed daily.

In Japan the feeding program for the rearing of marine larvae has been standardised as follows: oyster larvae, rotifer, copepods, or *Artemia* and a final diet of minced fish. However, rotifer is commonly used instead of oyster larvae because it is effective as initial food for fish larvae particularly those with smaller mouths (Watanabe 1982).

Rearing of larvae of the European sea bass (*Dicentrarchus labrax*) to juveniles (50 mg) is done using the following feeding schemes: rotifers and/or bivalve larvae for the first week; rotifers and *Artemia* for the next 4 days and *Artemia* only until the 7th to 8th week when metamorphosis is completed. Survival of the juveniles at this time is 20% reckoned from the time of hatching. After they reach 50 mg the sea bass larvae can be weaned successfully to a natural or prepared diet — moist or dry — using well-established techniques (Girin 1979).

The success in the mass production of sea bass fry coupled with the success of mass-producing sea bass fingerlings will trigger the development of sea bass as a major aquaculture species not only in the Philippines but also in the other countries of Asia and the Indo-Pacific region.

Already a number of Filipino fish farmers have attempted to culture the fish in ponds, some suffered failures and a few succeeded but the supply of fingerlings became the major drawback in their continued efforts to culture them. It is along this line that a few research institutions in the Philippines embarked on adaptive and basic research in order that fingerling production of sea bass could succeed.

It is therefore the objective of this paper to present the status of sea bass fingerling production in the Philippines and its identified problems and needs.

Status of Fingerling Production

Fish farmers encourage the entry of sea bass fingerlings into their milkfish ponds by opening of the pond gates. This way they get undetermined numbers

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of sea bass fingerlings while they continue the operation of their milkfish (*Chanos chanos*) ponds. Both milkfish and sea bass at the end of the culture period are harvested. Some fish farmers stocked their ponds with sea bass fingerlings and/or post-fingerlings and allowed them to grow subsisting only on what was available in the ponds. Some bought sea bass fingerlings and released them in ponds. They harvest the fish as soon as they reach marketable size (Fortes 1985).

Recently, studies on the development of culture techniques were conducted in the Philippines (Fortes 1985) that encouraged some fish farmers to formally culture sea bass using the techniques used elsewhere in Asia and the Indo-Pacific region. We are faced with a degree of reluctance by some fish farmers, because of the high mortality in their cultured stocks and the dwindling supply of fingerlings. Furthermore, sea bass fingerlings became very expensive because of the high expectation from it being an expensive food item.

In a number of culture operations of sea bass in the Philippines, the source of fingerlings is mostly from the wild. After the sea bass were spawning successfully in captivity in 1983, and fry was mass-produced, the hatchery became another source of fry. The main sources of sea bass fingerlings in the Philippines are as follows.

Collection from the Wild

Fry and fingerlings are collected from the wild at or near the spawning grounds along the sea near river mouths. Sizes of from about <1 g to 50 g are collected, and sorted from the milkfish and prawn collection, held in containers and brought to the shore after sufficient numbers are collected. These are transferred in another container and held until adequate numbers are accumulated. The fingerlings are then brought to the sea bass fingerling dealer and offered for sale. They are sometimes stocked directly in ponds and grown to post-fingerlings or half-grown and again offered for sale to sea bass growers.

Rearing of Hatchery-Produced Fry

In the rearing of hatchery-produced sea bass fry. SEAFDEC-AQD modified the procedure used in Thailand. The eggs are hatched and the larvae are fed initially with rotifer (*Brachionus plicatilis*) on day 3 when the larvae are ready to eat. The *Brachionus* is supplied with phytoplankton such as *Chlorella* or *Tetraselmis* and is given as larval food until day 15. The brine shrimp (*Artemia*) is added starting on day 10 and continued until day 25 in such a way that from day 15–25 only the brine shrimp are given as food. Beginning on day 20, cladocerans (*Moina* sp.) are added with the brine shrimps but beyond day 25 the brine shrimps are replaced completely with *Moina* or other cladocerans or entomostracans. A combination of minced trash fish and live cladocerans (*Mysis* sp.) may be fed until the fingerling stage by which time they can be stocked in ponds. At day 2 antibiotic is added, and day 9 grading is started.

At BAC attempts are being made to mass-produce sea bass fingerlings from fry produced from hatcheries. Sea bass larvae 7–21 days old are reared in different systems in order to develop appropriate techniques for fingerling production. In one study sea bass larvae are reared in containers connected to a recirculating system and fed with different kinds of natural food such as copepods, brine shrimps and minced trash fish. Microencapsulated whole egg fish larval diet will also be tested following the procedure described by Chow (1980). Another study tests the response of sea bass fry to formulated diet using some attractants to lure the larvae to eat the diet. Preliminary results are very encouraging. In this trial, the fry learned to accept the formulated diet very readily. The final outcome of this research will be a developed artificial diet to grow sea bass fry to fingerlings thereby contributing significantly to the attempts to mass-produce sea bass fingerlings with high survival in indoor tanks or in earthen nursery ponds.

The above methods of sea bass fingerling production still need a lot of improvement, thus research along this line has been identified as an important area.

Problems and Needs

The major problem in the production of sea bass fingerlings in the Philippines is the high mortality rates. These are experienced both in the rearing of larvae from the wild and that produced from hatcheries, and the rearing of fry to fingerlings in nurseries. A number of factors have been identified as causes of these high rates of mortalities: lack of personnel with adequate training in the larval rearing and brookstock development of sea bass; substandard management procedures in hatcheries and nurseries; inadequate facilities for larval and fingerling rearing; lack of inexpensive and appropriate food for the larvae; and limited knowledge of the biological requirements of sea bass larvae. As a result, survival from larvae to fry is estimated at about 20% and 10% from fry to fingerlings. In order to improve this situation the following must be worked on:

Development of Appropriate Food

Inappropriate and inadequate supply of food leads to early cannibalism resulting in poor survival of fry and fingerlings. In order to prevent this, inexpensive but appropriate food must be developed. Although natural foods and their amount have been identified and successfully fed to sea bass lavae, the supply of these kinds of food is still limited. The need, therefore, to identify alternative natural food organisms and develop culture techniques to mass-produce them is essential. A number of copepods, rotifers, cladocerans, en-

tomostracans, molluscan larvae and various species of phytoplankton have been found to be potential substitutes for the *Chlorella, Brachionus* and *Artemia* which are so far the best species used successfully in the larval rearing of many marine larval fishes, however, their mass production has not been as successful. Further investigations and concerted efforts are needed to succeed along this line.

In addition to the need to develop mass production techniques for alternative species of natural food, there is also the need to develop artificial feed that is attractive, acceptable and nutritious to the sea bass larvae. This will also lead to the development of artificial feed for rearing sea bass to marketable size. In previous feeding trials with formulated diets at BAC, the sea bass failed to accept pelleted feeds. As mentioned earlier, however, the use of attractants appeared to have succeeded in making the fry learn to accept an artificial diet very readily. Other artificial feeds such as the microencapsulated feeds are now available in the market, but their use in sea bass rearing needs to be further investigated.

Development of Safe Fish Grader

Chan (1982) developed a practical model which he used for sea bass fingerlings, and claimed that it was effective and resulted in zero mortality. In the commercial minnow farms in Arkansas, USA, graders made with wooden frames and small and very smooth wooden sticks that form a screen are used very effectively in sorting out the various sizes of minnows that are used for bait. Modifications of existing ones or development of new ones that are effective, efficient and safe to sea bass fingerlings need to be investigated.

Research Needs

The needs of sea bass fingerlings production in the Philippines are many: improvement of hatching rate; increased survival of larvae to fry and fry to fingerlings; development of appropriate food to minimise 'shooters' and prevent cannibalism; development of effective and efficient fish grader; identification of other natural food for larvae; and design and construction of facilities for fingerling production. In view of these identified needs, research should be pursued as follows:

A. Improvement of hatching rate and increased survival of fingerlings
   1. Broodstock maintenance and rearing: requirements of broodstock for maximum fecundity (physical, chemical and biological), development of simplified breeding techniques, environmental manipulation.
   2. Identification and development of mass culture techniques for other natural food for sea bass larvae and fry.
   3. Development of artificial feed for sea bass larvae, fry and fingerlings (including feeds for rearing to marketable size).
   4. Engineering aspects in sea bass fingerling production: (a) design and construction of efficient fish grader; (b) design and construction of rearing facilities for fingerling production.

B. Socioeconomics and marketing:
   Factors that affect sea bass fingerling production business; Market outlets for sea bass fingerlings; Stability of the fingerling industry structure.

With proper support, the pursuit of these identified needs and the successful generation and utilisation of technologies for sea bass fingerling production could bring sea bass aquaculture to a level that at least approaches that of the more developed aquaculture species.

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Development of Artificial Feeds for Sea Bass *(Lates calcarifer)*

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Sea bass *(Lates calcarifer)* is often harvested in milkfish ponds in the Philippines where it grows to marketable size. Its growth and survival in ponds can be a good indication of its potential for culture in brackishwater ponds.

The culture of sea bass was started in Thailand a few years ago, and Sirikul (1982) reported two methods of culturing them: pond and net cage culture. Sea bass culture, however, is dependent on the supply of trash fish because of the unfavourable response of the fish to artificial pelleted feed.

The solution to feeding several carnivorous species has been the use of fresh wet diets, such as fish or slaughterhouse waste that could be added to animal or plant meals to increase their nutritive value or as binders (Ghittino 1972).

The success achieved in the feeding of other carnivorous species with artificial diets could possibly provide solutions to the development of a suitable artificial feed for sea bass. Consistent with the effort to develop culture techniques for sea bass, this study was undertaken with the wider objective of exploring artificial feeds for sea bass. The other specific objectives were: (1) to compare fish meal and trash fish as animal protein source in the diet; (2) to test the effect of different methods of trash fish processing; and (3) to compare pelleted and moist diet forms on the growth and survival of sea bass in earthen ponds.

Materials and Methods

The sea bass fry were obtained from Tigbauan hatchery of Southeast Asian Fisheries Development Centre (SEAFDEC). The 45-day-old fry weighed 0.18–0.57 g and were 2.3–3.7 cm long. They were reared initially in fibreglass tanks for 7 days prior to culture in earthern ponds. During this period, the fry were weaned from the mixed diet of trash fish and *Artemia* by gradually replacing it with the experimental diet. After the weaning period, the fish, with an average weight of 0.3602 g, were stocked in 100 m^2 earthen ponds and exposed to five different dietary treatments. Two treatments had fish meal as the animal protein source given in pellet or mashed form and the three treatments had trash fish processed raw, pasteurised or sun-dried, as the animal protein source.

Each treatment had three replicates and distributed at random among the fifteen 100 m^2 ponds. Five isonitrogenous (40%) and isocaloric (3700 ME) diets were formulated. The diets were prepared using animal and plant protein at 1:1 ratio. The ingredients used were soybean, copra meal, wheat flour, rice bran and vitamin premix. As specified for each treatment, the diets contained either fish meal or trash fish as animal protein source, processed and preserved as specified for each treatment. The amount of ingredients used was computed by the cut and try method (Table 1). The ingredients used were ground and sieved.

Table 1. The composition of the five formulated diets (%).

Ingredients	Diet I	II	III	IV	V
Trash fish	—	—	*30.8	**30.8	***30.8
Fish Meal	39.2	39.2	—	—	—
Soybean meal	29.2	29.8	26.4	26.4	26.4
Copra meal	14.6	14.9	13.2	13.2	13.2
Wheat Flour	10.0	10.0	20.5	20.5	20.5
Rice Bran	6.0	3.1	6.2	6.2	6.2
Salt	—	2.0	2.0	2.0	2.0
Vitamin Premix	1.0	1.0	1.0	1.0	1.0

* Raw trash fish.
** Pasteurised trash fish.
*** Sun-dried trash fish.

The trash fish was homogenised by grinding it with a meat grinder. Dry ingredients were first thoroughly mixed before addition of the wet components of the diet. Wheat flour was cooked before adding it to the mixture. Moist diets were preserved by lactic acid fermentation, and given to the fish in dough form. Pellet feed was given to the fish in 2 mm size in the first 2 months and in 5 mm size in the succeeding months.

The fish were given feed at a rate of 10% of its body weight for the first 30-day culture period. The feeding rate was reduced to 8% on the 60th and finally to 4%

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on the 90th day. The adjustment of the amount of feed given was based on the fish sample taken every 30th day of the rearing period. The mean weight of the fish was recorded for each sampling.

Data gathered was analysed statistically using analysis of variance.

Results

The composition of the five experimental diets given to the fish is presented in Table 1. Through the combination of plant and animal (1:1 ratio) as protein source, about 40% protein and 3700 ME were incorporated in the five diets. The preservation of the moist diet involved the monitoring of pH, and observations showed that fermentation took place 7 days after mixing, with the drop in pH from a range of 6.75–6.80 to a range of 4.24–6.08, reaching a maximum 45 days later with a range of 2.60–2.95. The pH values increased to a range of 4.30–4.65 on day 60 and slightly increased up to 4.30–4.75 on day 105. The preservation of the diet by fermentation was shown by the drop in pH values on day 7 and was lowest on day 45. The lowering of pH in the 1st 45 days was maybe due to the production of lactic acid and the slight increase in pH from day 60 to day 105 was possibly due to the reduction of lactic acid into alcohols (Morrisson and Beryel 1975).

The growth, production and survival data of sea bass in ponds given the five experimental diets are summarised in Table 2. There was no significant difference among the five experimental diets ($P > 0.05$). The mean biomass production of sea bass fed a trash diet was 71.7 kg/ha for pasteurised trash fish diet, 70.5 kg/ha for sun-dried trash fish and 63.4 kg/ha for raw fish. There was a marked difference in the production of sea bass fed with pelleted and mashed fish meal. The pelleted fish meal had a production of 70.4 kg/ha while mashed fish meal gave only 56.4 kg/ha. With respect to survival, the highest rate was obtained in pasteurised trash fish, 90.0%. Fish fed with raw trash fish had 72.0% and sun-dried trash fish, 52.7% while fish meal diets had a survival of 76.7 and 56.7% for mashed and pelleted feed respectively. The growth data are summarised in Table 2 and these values were used to calculate the growth curve using the equation: $Y_t = W_0 e^{bt}$ where Y_t — calculated growth, t — time, W_0 – initial weight, b – constant (Grossman 1974).

Discussion

The interpretation of data should be done with care because of some major problems encountered which led to experimental errors that could have masked the treatment effect.

The size of the fish at stocking was comparatively small. Thus during the experiment, the fish were still in the lag phase when it was terminated and exponential growth was not attained. The exponential growth could have possibly shown the differences between treatments. Avance (1984) and Chou et al. (1985) used larger sea bass at stocking, initial weight of the fish stocked ranged from 22.6 to 27.6 g and 19.1 g respectively, and there were differences among experimental diets because the fish reached exponential growth during the period of culture. This period could possibly be the time when feed quality would most likely have a pronounced effect on fish growth because of the necessity to supply the fish with adequate amounts of nutrients to sustain a rapid gain in weight.

Table 2. The summary of growth (g), production (g) and survival (%) of sea bass given five different diets. All were 0.36 g at day 0.

Treatments	Replicate	Days of Culture 20	54	83	114	Production 100 m^2	Survival	Feed conversion
I	1	3.8	9.7	16.2	15.4	660.0	86	8.5
Fish meal	2	5.0	26.0	68.6	58.9	884.0	30	6.4
(pellet)	3	5.0	3.1	8.8	20.9	565.4	54	9.9
II	1	6.8	18.0	26.0	26.4	898.4	68	4.1
Fish meal	2	3.0	4.2	6.3	9.6	307.8	64	12.0
(mashed)	3	3.0	6.5	8.6	9.9	486.3	98	7.6
III	1	3.1	15.8	10.0	37.8	1 097.0	58	3.2
Trash fish	2	3.3	5.8	4.4	14.9	447.0	60	7.9
(raw)	3	1.6	6.4	31.3	7.3	357.0	98	9.9
IV	1	3.5	12.3	20.9	17.2	791.1	92	4.3
Trash fish	2	4.4	5.4	8.3	7.1	708.4	100	4.8
(pasteurised)	3	4.7	11.8	23.5	16.7	652.7	78	5.2
V	1	5.5	15.6	52.0	54.0	864.7	32	5.9
Trash fish	2	9.3	14.5	30.0	24.4	682.8	56	7.5
(sun-dried)	3	2.9	4.4	23.8	16.3	570.0	70	9.0

Also, a wide variation in the survival per pond in a treatment was observed. The size-group histogram showed that the presence of several large individuals in a pond has a marked effect on survival. Teng and Chua (1978) noted that starvation occurs among fish populations where size hierarchy was established. The physical presence of large individuals inhibited the smaller fish from feeding satisfactorily and the dominance of feeding and space by a few larger fish in a restricted culture area can cause death of smaller individuals due to starvation. Further, it was also possible that the larger sea bass preyed on the smaller ones thus resulting in a decline in survival on some of the treatments.

Lastly, the weaning period may have been possibly too short to make the diet acceptable to the fish.

Although no statistical differences in production, survival and food conservation ratio were observed between treatments, it is quite plain that there is a marked variation between fish fed with pasteurised, raw and sun-dried trash fish and fish meal diets. The pasteurised trash fish had a better production compared to raw and sun-dried trash fish. This may be attributed to the deactivation of enzyme thiaminase and destruction of some harmful bacteria during heating; thus improving the feed quality of pasteurised trash fish over that of sun-dried and raw trash fish. This observation was also reported by Lovell (1979) for catfish fed with pasteurised, raw and sun-dried catfish waste. Moreover, pasteurised trash fish diet still gave better production compared to fish meal diets. This may be due to some unknown growth factors in the trash fish which could have been degraded during processing it into fish meal, the difference in enzyme thiaminase activity, or due to differences in the organoleptic attractiveness of the two products.

In terms of food conversion ratio, the pasteurised trash fish diet still performed better as indicated by a low FCR compared to the rest of the trash fish diets. This may be due to the fact that pasteurised trash fish had less enzyme thiaminase and contained higher levels of nutrients compared to the rest of the diets. With regard to fish meal diets, the mashed fish meal gave a lower FCR as compared with the pelleted feed although the latter gave better production. It was observed that the fish would not feed on a hard and dry pellet but would eat the pellet once it had sufficiently soaked and absorbed water. The leaching out of the nutrients, during the time it stayed in the water could be the reason for the high FCR. Mashed feed, however, was consumed immediately, which most likely minimised the leaching-out of nutrients. The unfavourable response to dry pelleted feed has also been observed by Avance (1984); and Chou et al. (1984) maintained a moisture level of 20% for the fish pellets given to sea bass. The palatability of moist pasty feed has also been demonstrated in other carnivorous species such as eels.

In terms of survival, the pasteurised trash fish performed better than the rest of the diets. The survival of sea bass in individual ponds, however, has been affected by the size hierarchy. The presence of large individuals in a pond apparently resulted in a decreased population size.

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Growth of Introduced Larvae and Fingerlings of Sea Bass *(Lates calcarifer)* in Tahiti

Jacques Fuchs*

THIS report is a further extension of research work at the Centre Oceanologique du Pacifique (COP) in Tahiti to select the most important potential species for aquaculture.

Sea bass, *Lates calcarifer*, was selected along with grouper (*Epinephelus* sp.) as one of the most promising species for aquaculture for the following reasons: It is an economically important food fish in many tropical and subtropical areas (Rabanal et al. 1982; Tseng 1983), and has been cultured for many years in such countries as India, Pakistan, Indonesia, Thailand, Singapore and Malaysia.

Sea bass are fast-growing and can be reared in ponds or net cages to a commercial size of 600–800 g in less than 1 year (Anon 1983). Its tolerance to environmental changes is quite good as is its resistance to handling and disease.

The fish used in our experiments were imported from the Primary Production Department of Singapore.

General experiments were conducted in 1985 and 1986 to demonstrate the ability of sea bass to adapt to captivity and to a new environment. The growth potential was studied using artificial dry diets in tanks, then in floating net cages.

Adaptation of sea bass fry to compounded diets at an early stage was studied over 5 months on three batches of 40–50-day-old larvae. The larvae were obtained from a larval-rearing experiment at COP in three separate tanks, with 15-day-old larvae imported from Singapore.

Grow-out experiments were carried out in tanks in the preliminary experiments and extended to a large number of fry in floating net cages.

Design of Experiments

During the first experiment (weaning, 40–80 days from hatching), three batches of fry obtained after three different larval-rearings were reared in three tanks (1.5 m^3) and adapted to dry pellet at three sizes (60, 120 and 200 mg mean weight).

In the second experiment (nursery, 80–175 days from hatching), 5800 fry, average mean weight 1 g, coming from the first experiment were mixed and dispatched in eight tanks after grading. They were held under nursery experiments for 3 months until they reached 25g mean weight, and were fed pelleted diet 2 (Table 1) with frequent grading.

Table 1. COP diet formulas used for weaning, nursing and grow-out periods, and proximate analysis.

Components	Weaning diet formula 1 (%)	Grower diet formula 2 (%)
Normal fish meal 72	35	33
Meat and bone meal 50	5	4.7
Fish Protein Concentrate (CPSO80)	21	18.9
Soya bean meal 47	8	10.3
Wheat	4.5	8
Corn	6.	0
Leaf protein concentrate	1.5	2.8
Dried whey	0	3.7
Lactic yeast	9	9.4
Algae extract (guaranate)	2	2
$CaCO_3$	0	0.5
$CaHPO_4$	0	0.9
Vitamin mix	3.5	1.9
Red Capelin oil	2	3.7
Corn oil	2.55	0
Butyl Hydroxy Toluene	0.01	0.01
Proximate analysis, % (as fed)		
Protein content	56	55
Lipid content	16	12
Ash content	7.6	8
Moisture	3.2	6.4

The third experiment (grow-out in tanks) followed the growth of two batches of sea bass fingerlings fed on pelleted diet (formula 2) throughout the 10-month experiment. We used 72 fingerlings from the first trial, originated from the wild, with an average initial weight of 35 g; 94 juveniles from the second trial at 0.2 g, and grown at COP until their reached 25 g.

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The fourth experiment on grow-out in net cages involved two trials in cages (8 m^3) conducted at three initial densities of 30, 60 and 120 fry/m^2 or 15, 30 and 60/m^3. The choice of such densities was prompted by the average density values traditionally used for sea bass grow-out in cages at Singapore: 44 fry/m^2 (Anon 1983). The experiment lasted 6 months, with a 1-month lag between the two trials, due to a limited number of fry of the same weight. Fingerlings were 160 (Trial 1) and 180 days old (Trial 2).

Rearing Conditions

For the weaning and nursing period (40–75 days from hatching), rearing conditions in 1.5-t circular tanks were similar to those described by Barahona-Fernandez and Girin (1976) for environmental parameters. Salinity was maintained at 25‰ during the weaning period. The feeding schedule during the weaning included live *Artemia* for 5 days, frozen *Artemia* for 10 days and pelleted diet after 3 days. The amount of pelleted diet was adjusted to feeding behaviour and size of the fry, in a range of 4–1.5% of body weight/day. Automatic feeders were used to distribute feed continuously for 8 .hours/day. The fabrication of the two formulas is described in AQUACOP (1979).

Grow-Out

Rearing conditions in the 1.5-t tanks were the same as those in experiments 1–2, except that salinity was increased to 35‰ and water exchanged at the rate of 100 l/day.

Experiments were carried out during the rainy season (October 1985 to May 1986), with water temperatures 28°C and salinity 35‰. Current speed never exceeded 0.5 m/sec, and varied according to weather conditions. A pelleted diet (formula 2) was continuously distributed for 8 hours each day in the experimental tank. An automatic feeding system in the net cage was programmed to feed every 30 min during each 12-hour period.

Results

Experiment 1

Final weaning results are indicated in Table 2. The method used for weaning sea bass fry on a compounded diet produced 5800 fry in 80 days, with a 54% survival rate and a density below 1 larva/l.

There was a significant growth rate during these 40 rearing days. Average weight increased from 0.1 to 1.1g and mean length from 2 to 4.5 cm. Coefficient of condition was close to 1.2 and 1.4, indicating good health.

Larvae accepted pelleted diets after an overlap of 10 days on live and frozen *Artemia*. Amount of fresh food included 3% live *Artemia* and 10% frozen *Artemia*. In our rearing conditions, the final conversion ratio reached 1.6:1 as fed.

Weaning results in each before and after grading at day 55 are given in Table 2. Survival rate at day 80, the end of the weaning period, ranged from 46 to 66% and the best results were observed in tank 3 where fish exhibited the highest weight at the start of the weaning period. But such a difference was not significant. Cannibalism of fingerlings was noticed, and the smaller and weaker fish were probably eaten by the larger ones.

Experiment 2

Nursing results for 5800 fingerlings coming from experiment 1 are given in Table 3. After 95 days of rearing, a survival rate of 87% was achieved with 10% mortality occurring between 15 and 50 days when the fingerlings were fed formula 2 (Table 1) of the pelleted diet.

Average stocking density per tank increased from 0.5 to 6 kg/m^3, and 1 larva/2 l to 1 larva/5 l.

Growth promotion was fair during the nursing period and average weight increased from 1 to 25 g in 3 months, with the total length of fingerlings reaching 12.7 cm.

Table 2. Comparative results of survival, growth and feeding rates during weaning on pelleted feed for three batches of *Lates calcarifer* fry with different initial mean weight. Each batch is graded in three categories for 55-day-old fry.

Batch	Age from hatching	Number	Survival %	Mean weight (g)	Mean length (cm)	K Coeff	Cumulative conversion ratio	Density (fry/l)
	40	4990	100	0.07	1.7	1.3	—	3
1	55	2638	52	0.19	2.5	1.2	6	1.8–0.6
	80	2278	46	1.07	4.4	1.25	1.6	0.5
	45	3886	100	0.12	2.1	1.3	—	2.6
2	55	3336	86	0.17	2.4	1.2	4.6	2.2–0.7
	80	2254	58	1.08	4.4	1.3	1.5	0.5
	45	1990	100	0.20	2.5	1.3	—	1.3
3	55	1485	74	0.32	2.9	1.3	4.2	1.0–0.3
	80	1323	66	1.32	4.7	1.3	1.7	0.3

Table 3. Nursing period results in experiment 2 for 5800 sea bass fingerlings between 1 and 25 g; with grading after 15, 50 and 75 days.

Age from hatching (*days*)	Duration (days)	No. fry	Survival (%)	Mean weight (g)	Mean length (*cm*)	Density fry/l	Tank volume (m^3)	Cumulative conversion ratio (as fed)
80	0	5855	100	1.13 ± 0.02	4.50	0.5	12	+
95	15	5721	97.7	2.07 ± 0.05	5.50	0.5	12	1.2:1
130	50	5137	87.7	5.95 ± 0.12		0.3	15	0.8:1
155	75	5073	86.6	16.63 ± 0.29	11.10	0.2	21	0.8:1
175	95	5049	86.2	25.58 ± 0.36	12.70	0.2	21	0.9:1

Maximum growth rate observed was noticed between day 50 to 75: mean weight increased from 6 to 17 g and the daily weight increase was 4.1%/day.

Daily amount of feed was adjusted between 5 and 3% body weight and conversion ratio reached 0.9:1 as fed with a maximum value of 1.2:1 during the first 15 days. The relationship between time of grading and survival rate was clear. Survival rate for every batch surpassed 95%, regardless of weight of fish.

Experiment 3

Results of growth tests are reported in Table 4. *Lates* fingerlings from the wild (trial 1) or from hatchery (trial 2) readily accepted a pelleted feed and final survival rate was 90% after 10 months. Mortality was due to loss of fish jumping out of tanks. No injury appeared on fish after handling.

Amount of feed was adjusted to larval requirements between 4 and 1.5% of body weight/day, providing a mean conversion ratio of 1.9:1 and 1.5:1 in trials 1 and 2. Activity stress between 4 and 6 months of rearing in trial 1 caused an increased conversion ratio up to 6:1.

Experiment 4

General results of the two growing-out trials are given in Table 5. In all cages, survival rates exceeded 85% after 6 months of rearing. Survival rates were not correlated with the initial stocking densities in the range tested.

Mortality was mainly related to casual losses at samplings and nets shifting. The cage stocked at 30 fry/m^3 in trial 2 was the only one with 10% mortality within 4 days of stocking. Final mean weights varied in the range 630–690 g (Table 5). Mean weights were significantly better for the cages stocked at the lowest densities (15 fry/m^3).

Conclusion

Preliminary results obtained with sea bass fingerlings indicated that this species performed quite well in captivity and showed adaptability to a new environment. The fingerlings ate actively on a dry feed diet after 2 months of rearing.

These preliminary results achieved at COP prove the ability of sea bass to be raised in net cages at high stocking densities. Marketable size (500 g mean weight) was obtained in about 12 months from hatching eggs in local conditions, with a final density of up to 30 kg/m^3 thus making this species the most interesting for aquaculture development in Tahiti.

Table 4. Growing period data with 72 sea bass fingerlings from the wild (trial 1) or produced in a hatchery (trial 2), fed on a 55% protein and 12% lipid diet.

Trial	Duration (*days*)	No.	Survival (%)	Mean weight (*g*)	Daily wt increase %/day	Conver. ratio (as fed)	Density (kg/m^3)
	0	72	100	35	—	—	0.8
	36	72	100	71.9 ± 4.9	2.0	1,4:1	1.7
	115	68	94	159.9 ± 9.6	0.9	1,5:1	3.6
1	170	68	94	179.5 ± 11.6	0.2	6,3:1	4.1
	220	67	93	315.8 ± 21.9	1.1	1,1:1	7.1–4.7
	270	67	93	397.5 ± 31.3	0.5	2,1:1	5.9
	300	67	93	428.6 ± 34.1	0.2	3,5:1	6.4
	0	94	100	24.2 ± 2.8	—	—	0.8
	28	94	100	60.1 ± 4.8	3,1	0,6:1	1.9
	105	90	96	149.9 ± 6.9	0,8	1,6:1	4.5
2	145	88	94	187.7 ± 9.5	0.5	2,6:1	5.5
	190	88	94	239.9 ± 11.4	0,6	1,6:1	7
	260	87	93	320.6 ± 18.5	0,4	2,1:1	9.3–3.5
	300	85	90	472.1 ± 23.8	0,8	1,2:1	5.0

Table 5. Comparative results of survival, growth and feeding rate during two *Lates calcarifer* fry growing trials in net cages at three initial densities. Fry were fed on a 55% protein and 12% lipid compounded diet.

Initial stocking density (fry/m^3)	Experiment duration (*days*)	Initial No.	Final No.	Initial mean wt (*g*)	Final mean weight (*g*)	Daily wt increase (*%/day*)	Final conversion ratio (as fed)	Stocking density **(kg/m^3)**	Production (kg/cage)
				Trial 1					
15	180	120	107	30.6 ± 1.2	692 ± 22	1.73	1.7:1	9.3	74
30	180	240	232	30.6 ± 1.2	634 ± 14	1.68	1.5:1	18.4	152
60	180	480	460	30.6 ± 1.2	633 ± 10	1.68	1,5:1	36.4	291
				Trial 2					
15	187	120	117	32.4 ± 5.7	674 ± 17	1.62	1.6:1	9.9	79
30	187	240	208	32.4 ± 5.7	677 ± 16	1.62	1.5:1	17.6	141
60	187	480	469	32.4 ± 5.7	648 ± 10	1.60	1.7:1	38.0	304

These encouraging results with sea bass put this species among the candidate species for future aquaculture in Tahiti. It has a fast growth rate, accepts readily a new environment, and feeds easily on pelleted feeds. Further studies should be conducted on each step of its life cycle in order to put in action aquaculture methods which can be transferred throughout the world.

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Diseases

Diseases of Cage-Cultured Sea Bass *(Lates calcarifer)* in Southwestern Thailand

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DURING the past decade, sea bass (*Lates calcarifer*) has become the most promising commercial marine food fish in Thailand. Because of low cost and easy construction, over 95% of the sea bass production is done in net cages floated at the mouth of a river or a canal. The most intensive areas of cage culture are located in Satul, Trang and Krabi provinces in the southwestern part of Thailand, where 200 t of sea bass are harvested annually.

Since the cages are floating in estuarine water, there are frequent changes in water quality. As a result of environmental problems, the fish suffer stress and their resistance to infectious diseases is lowered. Diseases may therefore result in significant losses.

Numerous diseases of sea bass have been reported in Thailand. The causative agents of these diseases are parasitic organisms, bacteria, viruses, malnutrition and environmental stresses. Among them, the presence of parasitic organisms is common in sea bass and the following parasites were reported: protozoans (*Cryptocaryon* sp., *Trichodina* sp., *Epistylis* sp. and *Oodinium* sp.), monogenetic trematode (*Diplectanum latesti*), digenetic trematodes (*Lectithochirium* sp. and *Pseudometadena celebesensis*), nematode (*Cucullanus* sp.) and crustaceans (*Caligus* sp., *Ergasilus* sp. and *Aega* sp.) (Ruangpan 1981, 1984).

In several disease outbreaks in sea bass cage culture, bacteria were reported as the most important pathogenic agent. *Aeromonas hydrophila, Flexibacter columnaris, Vibrio* sp. and *Pseudomonas* sp. were associated with such diseases (Buranapanidgiet and Danayadol 1984; Danayadol et al. 1984; Ruangpan 1984; Tonguthai 1985).

Recently, two chronic diseases in sea bass cage culture were reported from Songkhla Lake: lymphocystis, a viral disease, occurred during September–December 1982 and resulted in less than 1% mortality (Limsuwan et al. 1983); and a nutritional disease called 'kidney disease' in seabass was reported and hyperphosphorus was assumed to be the cause (Danayadol and Buranapanidgiet 1984a, b).

Sample Collection

Clinically asymptomatic and/or moribund sea bass and water samples were collected at monthly intervals from 26 cage-culture areas in Satul, Trang and Krabi provinces during October 1984–September 1985. Diseased fish were kept alive individually in plastic bags while water samples were preserved in BOD bottles kept in ice. Disease diagnosis and water analysis were performed mostly in the Fish Diseases Laboratory, Satul Brackishwater Fisheries Station on the day collected. However, some samples collected in Krabi were examined in the field. Detailed descriptions of disease symptoms, possible stress conditions, mortality rate and diet were recorded for each case.

Disease Diagnosis

At least three fish per case were necropsied as soon as possible after collection. After the fish were killed, gross external macroscopic examination was performed to search for parasites and clinical signs. Blood smears and wet mounts of fins, gill filaments and body scraping were observed under a compound microscope.

Internal examination for any lesions and parasties was performed. A sterile loop was used to transfer an inoculum from the kidney, liver, spleen and/or gills, external lesions and abdominal fluid onto bacteriological media and incubated at 25 and 37°C. Brain heart infusion (BHI) agar, trypticase soy agar (TSA), TSA with 1.5–2.0% NaCl and Cytophaga agar were used as general bacteriological media in this study. If necessary, impression smears of the kidney, liver and spleen were made, stained with Giemsa and examined under a compound microscope for pathogenic organisms.

Isolated bacteria were subcultured once or twice to get pure culture. Then, presumptive identification and biochemical tests were performed for bacterial identification (Buchanan and Gibbons 1975; American Fisheries Society: Fish health Section 1979).

Although various diseases of sea bass have been studied and documented, all of them deal only with the

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cage culture in the east and southwest of Thailand. This study was conducted to identify the pathogenic agents and to detect occurrences and relationships between various disease conditions in sea bass cage culture in southwestern Thailand, where environmental conditions are different from the east and southeast.

Water Analysis

Depth, transparency, current, temperature and salinity of water were examined in the field. Immediately after water collection, dissolved oxygen (DO) was fixed and analysed by Azide Modification of Winkler Method (Ameican Public Health Association et al. 1981). Finally, pH, alkalinity, nitrite (NO_2^-–N), nitrate unionised ammonia (NH_3^-–N) and phosphate ($PO_4^{\equiv}$) were examined.

Results

Incidence of Diseases

Disease occurrence in cage-cultured sea bass was observed every month throughout this investigation and a total of 426 disease cases was recorded. The highest numbers of 71 and 69 cases (16.7 and 16.2%) of the observed cases were recorded in November 1984 and January 1985, respectively. The lowest number of cases was recorded in May 1985 when only 6 cases or 1.41% of the observed cases were recorded. However, intermediate to high numbers of cases were continuously recorded during October 1984–March 1985 and June–July 1985 (Fig. 1).

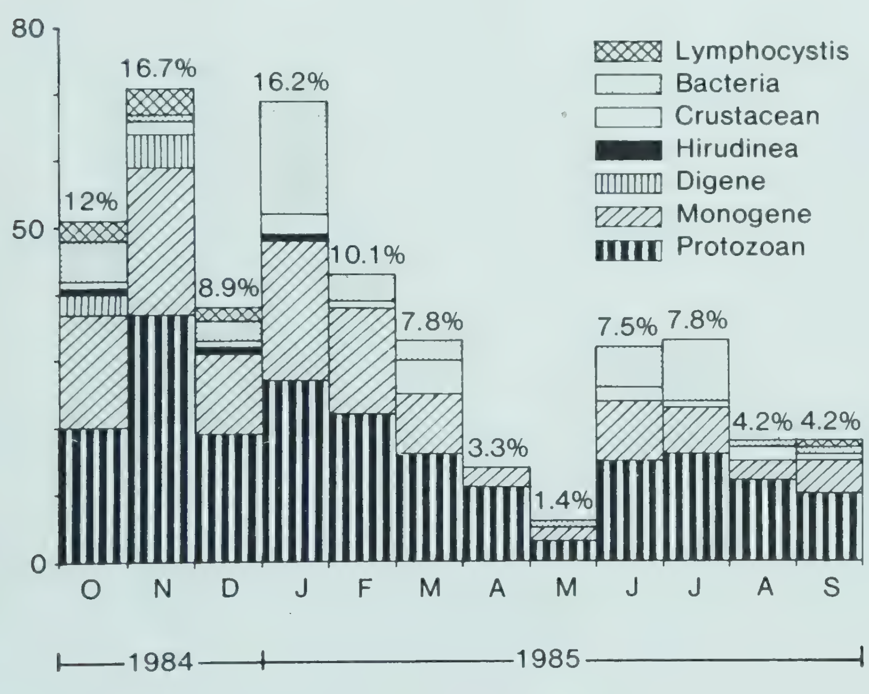

Fig. 1. Monthly incidence of diseases on cage-cultured sea bass in Satul, Trang, and Krabi provinces (October 1984–September 1985)

Bacterial and Viral Diseases

Fifty-two cases of bacterial diseases were recorded during this investigation, being involved in 12.2% of the observed cases. A peak of bacterial diseases of 17 cases was recorded in January 1985 while none of them was recorded in April 1985. *Vibrio* sp., *Aeromonas* sp. and *Pasteurella* sp. were found to be the major pathogenic agents of these diseases found their peaks in January 1985. Three cases of *Pseudomonas* infection were reported during this investigation.

Because of a lack of equipment, lymphocystis was the only viral disease detected. It occurred during during October–December 1984 and September 1985 and was involved in 2.4% of the observed cases.

Parasitic Diseases

Parasitic diseases constituted the major diseases in this investigation, being involved in 85.4% of cases. The aetiological agents of these diseases were found to be protozoans, monogenes, digenes, hirudineans and crustaceans. Among these organisms, protozoans and monogenes were the most commonly encountered parasites and were recorded throughout this investigation, being involved in 48.8 and 29% of the observed cases, respectively.

Trichodina sp., *Cryptocaryon* sp. and *Oodinium* sp, were the major protozoan parasites infesting sea bass. However, a few cases of *Henneguya* sp. were also recorded. Peaks of infestations of *Trichodina* sp, were recorded in November 1984 and January–February 1985, while *Cryptocaryon* sp. peaked in January and July 1985 and *Oodinium* sp. peaked in November 1984.

Records of infestations of *Diplectanum* sp., the major monogenic parasite, showed a marked concentration during October 1984–February 1985. The highest number of cases due to this organism were recorded in November 1984 and January 1985. A few cases of *Dactylogyrus* infestation were recorded during May–July 1985.

Digene (*Pseudometadena* sp.), Hirudinea (*Pontobdella* sp.) and crustaceans (*Aega* sp. and *Gnathia* sp.) were recorded in a few cases and caused no serious problem.

Water Quality

Results of water analysis from 26 sea bass cage-cultured areas were pooled, averaged in each month and plotted into curves as shown in Fig. 2. The average depth of water fluctuated between 3.9 and 4.8 m throughout this investigation. Transparency and salinity were high during January–April 1985 and low during July–September 1985. It was found that low water temperatures occured during December–January 1985. The lowest concentration of DO was recorded in October 1984, while the lowest concentrations of nitrite, nitrate and unionised ammonia were recorded in March 1985. In August 1985, the lowest pH and alkalinity and peaks of current, nitrite, unionised ammonia and phosphate were recorded.

Discussion

It was shown that diseases in sea bass cage culture in Southwestern Thailand during this investigation were most prevalent during October 1984–May 1985. Since

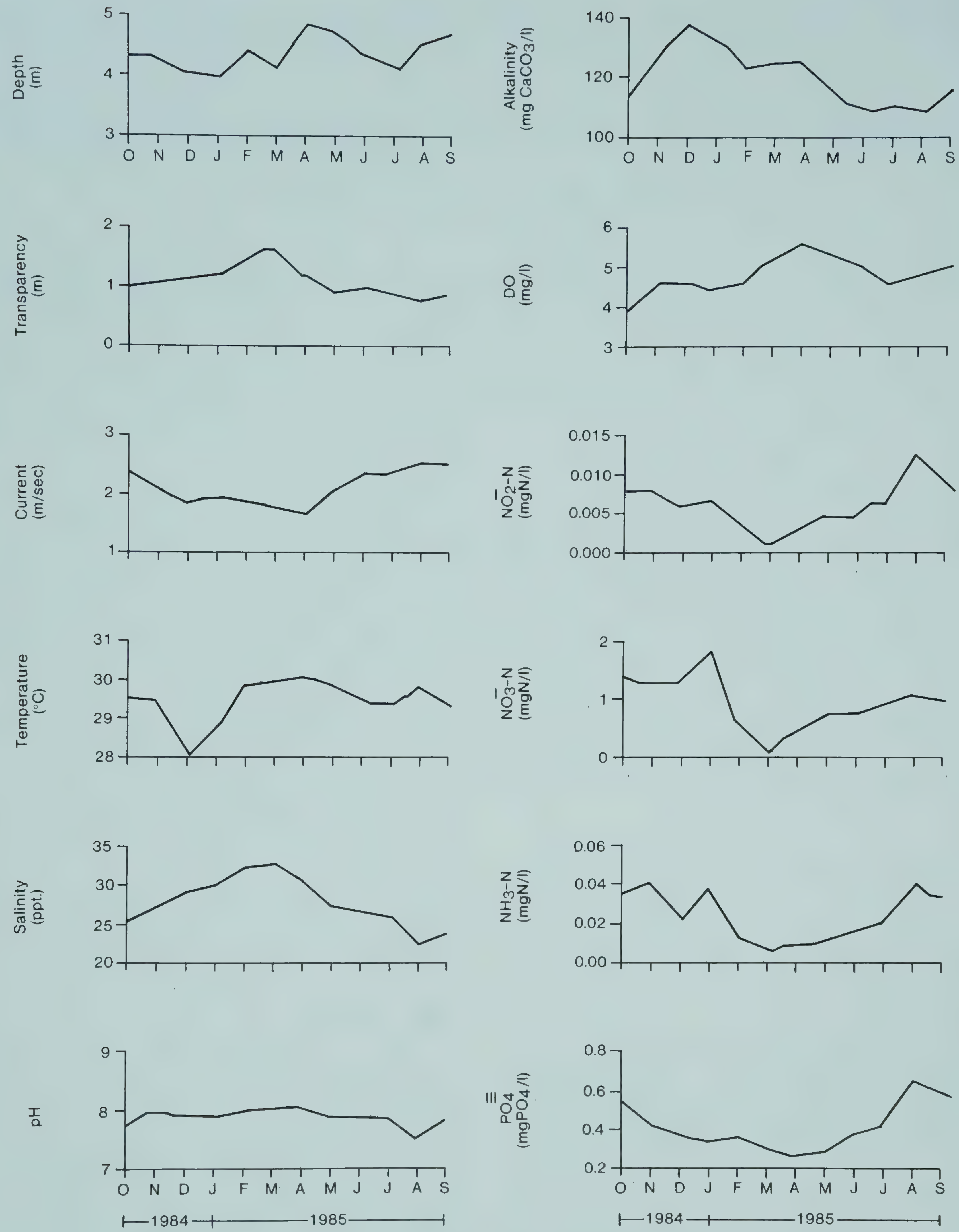

Fig. 2. Average physicochemical properties of water in cage-cultured sea bass in Satul, Trang, and Krabi provinces (October 1984–September 1985).

fingerlings were most severely infected, high numbers of cases during this period may have resulted from environmental stresses and stresses due to handling and stocking activities. However, a peak of cases was also noted in June and July 1985, the beginning of the rainy season. Therefore, decreasing salinity and increasing velocity and turbidity of water were initiated resulting in stress to the fish.

Protozoans were found to be the major aetiological agent of the observed cases and affected mainly fingerlings. Peak incidence of protozoan epizootics during October 1984–February 1985 may result from

stresses due to handling, new stocking and overfeeding. Lom (1970) suggested that protozoans may be harmless and feed on cellular debris from the host's surface under proper conditions, but their reproduction can reach massive proportions when the host is weakened.

Although monogenes were recorded throughout this investigation, a high incidence of them was recorded in October 1984–February 1985. These organisms were found attacking mainly the gills of sea bass of all sizes. However, infestations of monogenes, digene, Hirudinea and crustacean parasites caused no serious problem to the cage culture of sea bass.

Outbreak of bacterial infections in January 1985 was evidently due to handling, new stocking, overfeeding and adverse environmental conditions. It was noted that most of the bacterial diseases occurred as the secondary infection following parasitic infections.

Since all parameters of water quality were in the normal range throughout this investigation, it is suggested that seasonal rhythm of fish immune response may be involved in disease outbreaks. Yamaguchi et al. (1980) reported seasonal suppression of antibody formation in rainbow trout that under constant 18°C temperature, antibody levels of fish immunised prior to spring were much higher than in fish immunised prior to winter. Therefore, kinetics of antibody production in fish were seaonally dependent.

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Pathological Anatomy and Diseases of Barramundi *(Lates calcarifer)*

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Reports of diseases, pathogens and parasites which affect barramundi are few compared with those described for other fish species of comparative commercial and socioeconomic importance. Reports describing such agents in barramundi refer primarily to incidental findings or observations on wild fish; no systematic surveys which establish a spectrum of pathogens or diseases in any population, either captive or wild, are described. Our knowledge pertaining to diseases of barramundi is, therefore, very much in its infancy.

While a paucity of specific diseases data relating to barramundi exists, much is known regarding diseases, pathogens and parasites of many other freshwater, estuarine and marine fish. Attention is drawn to the diverse range of pathogens and potential pathogens described in cultured fish in Southeast Asia (Davy and Graham 1979). As is the case in many species subjected to intensive systems of management or culture, the intensive production of barramundi will undoubtedly result in outbreaks of disease caused by known or previously undescribed pathogens. What is thus important in the absence of detailed accounts of diseases of barramundi is a knowledge of those pathogens which are likely to infect barramundi, as well as the ability to accurately and rapidly diagnose these agents, and previously undescribed diseases in affected fish.

It must be stressed that an accurate diagnosis of disease is fundamental to successful treatment, control or eradication in any species and barramundi is no exception. This paper examines the comparative pathology of fish in relation to those pathogens and diseases likely to be encountered in intensified barramundi production, and in this context will describe essential anatomical and histological features of the barramundi. The paper also examines and defines our concepts of disease in fish and concludes with an overview of the principles of disease diagnosis and those laboratory facilities which are essential for the diagnosis of such disease. The importance of regional quarantine will also be stressed.

Diseases in Fish

Disease states in people and animals are usually readily recognised by the occurrence of clinical signs or pathological lesions caused by the disease or pathogen, which may or may not be followed by death. Such states do occur in fish and are obvious, even to the untrained observer, as in the case of fish kills or outbreaks of ulcerative skin lesions. Often, however, disease states in fish are not apparent, due to the difficulty in observing fish in their environment or due to the absence of clinical signs or lesions. Chronic heavy metal toxicoses and some protozoan or metazoan parasite infections, for example, may result in loss of production, growth rate and reproductive potential in the absence of clinical signs.

It is convenient, then, to define disease in fish as: 'Any factor or combination of factors which results in sub-optimal production.'

There are a multitude of factors which affect fish and which will result in sub-optimal production. These include viruses, bacteria, fungi, protozoa, metazoa, nutritional, toxic, environmental, managemental, neoplastic and idiopathic factors. These factors can be divided into infectious, non-infectious, and managemental.

While primary pathogens, which result in disease in the absence of other factors, do occur in fish, it is usual to find a complex of factors acting which, together, are ultimately expressed as disease. Of all these factors, stress is by far the most important. Stress may result from many factors, for example, overcrowding, inadequate nutrition, handling or inappropriate environment. The avoidance of stress is the single most important factor in the treatment and control of diseases in fish.

It is important that we do not become preoccupied with the infectious diseases. Non-infectious agents,

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particularly toxins, can effectively preclude successful aquaculture. Mass mortalities of fish in public waters associated with factory effluents and insecticide contamination have been reported by Alimon et al. (1983) in Malaysia, and Chinabut and Danayadol (1983) stress the importance of toxicological problems associated with herbicides and pesticides in Thailand. We have provisionally diagnosed toxicity due to endogenous or exogenous ammonia or high heavy metal levels in juvenile barramundi, characterised by profound vacuolar change in the central nervous system. MacKinnon (these Proceedings) has discussed this condition further.

Disease in barramundi, therefore, is likely to result from a complex of interacting factors. In order to appreciate that disease is occurring, accurate records of production and growth are required. In the event of disease occurring, the spectrum of infectious, non-infectious and managemental factors must be considered diagnostically, with emphasis on the avoidance of stress in treatment or control.

Comparative Pathological Anatomy of Barramundi

Fundamental to the successful diagnosis of disease in any given species is a knowledge of the anatomy and histology of that species. In order that gross and histopathological changes associated with disease can be meaningfully interpreted, the anatomy and histology of barramundi must be known.

The diseases discussed below are given as examples, which can be expected to cause serious disease in barramundi. In no way do the diseases mentioned constitute a complete list of diseases of barramundi and other and new diseases undoubtedly will occur. As in any new field of endeavour, we should train ourselves to expect the unexpected as far as diseases of barramundi are concerned.

Integument

The integument's intimate contact with the environment and its delicate epidermis make the integument especially prone to trauma, parasite attachment and a site of entry for pathogens. Many diseases, pathogens and parasites affect the integument of fish and integumentary changes are valuable indications of systemic infection. In particular, viraemic and bacteraemic infections frequently result in petechial or ecchymotic cutaneous haemorrhages with, in the case of bacteria, localisation in the dermis with subsequent ulceration.

Vibriosis is a severe, economically important septicaemic infection caused by *Vibrio anguillarum* and other *Vibrio* sp. which affects a diverse range of marine and estuarine fish species. Vibriosis is a serious disease of farmed barramundi in Singapore (Cheong et al. 1983) and Thailand (Chinabut and Danayadol 1983). It is also a serious disease in farmed grouper *Epinephelus tauvina* in Malaysia, Singapore and Thailand (Alimon et al. 1983; Cheong et al. 1983; Chinabut and Danayadol 1983) and has been incriminated in mass mortalities in milkfish fry, *Chanos chanos* in the Philippines (Lio-Po et al. 1983). High losses due to vibriosis can be expected in barramundi cultured in high salinities unless prophylactic measures including vaccination are taken. The disease is characterised by extensive cutaneous and systemic haemorrhages and localised cutaneous ulceration may occur.

Similarly, edwardsiellosis, a septicaemic disease caused by *Edwardsiella tarda*, in which localisation of the bacteria in the dermis occurs with subsequent ulceration has occurred in farmed barramundi in Singapore (Cheong et al. 1983) and may also be further expected. This disease occurs in a wide range of fish including pond cultured *Clarias* in Thailand (Kabata 1985). The agent is common in ornamental fish (Humphrey et al. 1986). Predominant lesions are haemorrhage and ulceration.

Haemorrhagic septicaemias due to *Aeromonas hydrophila* and *Pseudomonas* sp. may also be expected in barramundi with disease characterised by mortalities, ulcerations and haemorrhage. *Pseudomonas fluorescens* has been associated with diseased fry of tilapia, *Sarotherodon niloticus* in the Philippines (Lio-Po et al. 1983). *Aeromonas hydrophila* and *Aeromonas* sp. appear to be the most common cause of bacterial haemorrhagic septicaemia in the region. Aeromonal infections reported in farmed barramundi in Singapore (Cheong et al. 1983) and *Clarias batrachus* in Thailand, Indonesia, the Philippines; in *C. macrocephalus* in Thailand; in *Leptobarbus hoeveni* in Indonesia, and in ornamental fish in Singapore (Kabata 1985). Aeromonal septicaemia is currently one of the four most serious infectious diseases in Indonesia, affecting primarily *Cyprinus carpio* and *Clarias batrachus* (Djajadiredja et al. 1983). As with vibriosis, aeromonal septicaemia can be expected to be a major bacterial infection in cultured barramundi.

Infections with new or poorly classified bacteria may be a problem in barramundi.

Total mortalities have occurred in 10-day-old barramundi larvae, possibly associated with bacterial infection (Alimon et al. 1983) in Malaysia.

Viral diseases of warm water fish may cause cutaneous haemorrhages, erythema and ulceration. A suspect viral disease, characterised by ulcerative or erosive dermatitis, has occurred in *Clarias macrocephalus* fingerlings in the Philippines (Lio-Po et al. 1983). Viral disease such as *lymphocystis*, which causes nodular cutaneous proliferation any may occur in epizootics has occurred in barramundi fry in Singapore (Cheong et al. 1983) and can be expected further in barramundi. Lymphocystis has also been reported in siganids in the Philippines (Lio-Po et al.

1983). Epizootic haematopoietic necrosis virus (EHNV), an iridovirus of redfin perch (*Perca fluviatilis*) which is known to affect or be carried by other species in Australia, including Murray cod, *Maccullochella peeli*, may also cause disease in barramundi. Erythema in the brain and nostril region and focal pallor more caudally are prominent clinical signs in affected fish (Langdon and Humphrey, in press). The presence of cutaneous erythema and haemorrhages should always be regarded as evidence of possible viral infection.

Ulcerative syndromes do affect barramundi as well as a wide range of other fish species. A complex aetiology and pathogenesis involving a rhabdovirus, bacteria and fungi as well as environmental and toxic factors has been postulated as the cause of the epizootic ulcerative syndrome (EUS) of barramundi and other species in Southeast Asia and Papua New Guinea (Tonguthai 1985; Roberts et al. 1986; Frerichs et al. 1986). Ulcerative diseases of undetermined aetiology were also reported in *C. macrocephalus* in the Philippines (Lio-Po et al. 1983). A similar disease is present in Australia, with ulcerative lesions affecting a wide range of fish species, including barramundi, mullet (*Liza diadema*), saratoga (*Sclerophages leichardti*), long tom (*Strongylura krefft*i), rainbow fish (*Melanotaenia* sp.) sleepy cod (*Oxyeleotris lineolatus*), catfish (*Ariius* sp.), and mangrove jack (*Lutjanus argentimaculatus*). The pathogenesis in these cases is believed to be a primary epidermal necrosis due to virus or other cause, for example, parasitic infection, followed by systemic invasion with a pathogenic fungus. We have just confirmed the presence of a virus in barramundi which we postulate as the primary aetiological agent in this disease. This disease may be a major limiting factor to barramundi production in areas where it occurs.

Parasitic infections of the integument will affect barramundi as in most other fish species. The protozoa *Ichthyophthirius multifiliis* and *Cryptocaryon irritans*, the causative agents of freshwater and marine 'white spot' respectively are relatively non-host specific and can be expected commonly in cultured barramundi. This parasite may also invade the gills in high numbers. White spot disease is a serious disease in cultured *L. calcarifer* in Thailand (Chinabut and Danayadol 1983). Serious epizootics of *Ichthyophthirius multifiliis*, with great losses to fish farmers have long been recognised in Indonesia (Djajadiredja et al. 1983). *Ichthyophirius multifiliis* has also caused deaths in fry and fingerlings of *Puntius gonionotus* and *Cyprinus carpio* in Malaysia (Alimon et al. 1983). *Ichthyophthirius* is also reported from numerous other species in Southeast Asia in domestic fish stocks, including *Helostoma temmincki, Lebistes reticulatus, Osphronemus gouramy, Pangesius macronema, Pangesius* sp., *Rasbora* sp., *Tilapia nilotica* and a range of ornamental species (Kabata 1985). Other non-host specific protozoa such as *Ichthyobodo (Costia) necator* will likely affect barramundi, causing severe irritation, epidermal necrosis and secondary infection.

The skin 'flukes,' such as *Gyrodactylus* sp., *Dactylogyrus* sp. and *Diplectanum* sp. which occur on other *Lates* species (Paperna 1980) will also be a problem where they occur in intensively cultured barramundi. *Gyrodactylus* has been reported in numerous fish in Southeast Asia including *Clarius batrachus, Clarias macrocephalus, Cyprinus carpio, Ophiocephalus striatus, Pangesius* sp. and *Trichopterus pectoralis* (Kabata 1985). *Laenaea* sp., *Opistholernaea* sp., *Ergasilus* sp., *Argulus* sp. and othe crustacean parasites occur on barramundi and other *Lates* species (Paperna 1980) and can cause skin and gill damage. *Laenaea cyprinacea* is a serious pathogen in Indonesia causing epizootics in fish including the common carp *Cyprinus carpio*, Java carp *Puntius javanicus*, and giant gourami *Osphionemus gourami* (Djajadiredja et al. 1983).

Integumentary parasites which we have seen on barramundi include several morphologically different crustacean parasites, including *Argulus* sp. We have also seen large red nematodes, probably *Eustronlides* sp., encysted in the dermis in haemorrhagic foci. A digenean trematode parasite which apparently migrates through the dermis, then through the underlying scale to encyst in the dermis, leaving distinct holes in the scales, has also been seen in high numbers. The damage caused by parasites may result in epithelial necrosis and subsequent invasion by pathogenic bacteria or fungi. The potentially pathogenic protozoan *Henneguya* sp. has also been recorded from *Lates* species (Paperna 1980) and we have seen this parasite from the skin of Australian barramundi.

Gills

Like the skin, the gills are in direct contact with the environment. The gill structure is extremely delicate and prone to trauma and invasion by parasites and microbial pathogens.

Gills should always be examined in smears and histological sections in any fish health investigations as they are frequently involved in disease processes, especially parasite infections, under conditions of high population densities.

Numerous protozoan and metazoan parasites can be expected to affect the gills of barramundi. *Trichodina* sp. occur in the gills of most species and we have observed *Trichodina* in gills of barramundi in Australia. Trichodiniasis has caused serious losses in cultured *L. calcarifer* in Thailand (Chinabut and Danayadol 1983) in which poor management was considered the major cause of the disease outbreak. *Chilodonella*

hexasticha and *C. cyprini* can be expected, and are serious pathogens, causing profound epithelial hyperplasia and disturbance of gaseous exchange, excretion and osmoregulation. Major fish kills due to *Chilodonella* have occurred in Australia (Ashburner and Ehl 1973, Langdon et al. 1985). *Myxobolus* sp. causes severe annual losses in Java carp fry *Puntius javanicus*, in Indonesia with encystment of the parasites in the gill filaments (Djajadiredja et al. 1983). Other protozoans such as *Ichthyophthirius*, and *Thecamoeba* may also be expected. The dactylogyrid gill flukes do occur in barramundi and can be expected to be pathogenic in high numbers. Gill fluke disease has caused serious losses in cultured *L. calcarifer* in Thailand (Chinabut and Danayadol 1983). The dactylogyrid *Diplectanum* sp. occurs in *lates* species and induces gill epithelial hyperplasia (Paperna 1980).

Alimentary Tract

Protozoan parasites, for example, coccidia, and an extracellular protozoan parasite, possibly *Cryptosporidium*, which we have observed in Australian barramundi, and other unicellular agents such as algae may be expected to cause disease of the alimentary tract in baramundi. We have seen metazoan parasites encysted in the musculature and serosa of the stomach and intestine in barramundi, with extensive fibrosis of adjacent tissue.

The liver and pancreas in barramundi are combined in one organ, the hepatopancreas, with strands of exocrine pancrease containing the islets of Langerhans peripheral to the pyloric caecae. The hepatopancreas is a trilobed organ which encloses the stomach, intestine and pyloric caecae centrally. A range of bacterial and viral pathogens as well as toxins can be expected to produce hepatopancreatic lesions. EHN virus, for example, results in multifocal hepatocellular necrosis (Langdon and Humphrey, in press). *Mycobacterium* sp. localise in visceral organs and tissues, resulting in granulomas in which the typical acid-fast bacilli may usually, but not always, be seen. Granulomatous lesions may be expected in the hepatopancreas of barramundi with mycobacteriosis and nocardiosis. Necrosis and abscession can be expected in the bacterial septicaemias where localisation in viscera occurs with, for example, *Aeromonas* sp., *Pseudomonas* sp., and *Vibrio* sp.

Kidney

The kidney of the barramundi consists of tubular epithelium and haematopoietic tissue. Pathological processes may involve either the tubular epithelium, the haematopoietic tissue or both elements. EHN virus, for example, results in massive necrosis of the haematopoietic tissue with sparing of the tubular epithelium. A similar range of diseases and pathogens which affect the liver may be expected in the kidney.

Spleen

In the spleen, haemoglobin from damaged erythrocytes is converted and stored as haemosiderin. Splenic haemosiderosis may be a valuable indication of toxic or infectious causes of erythrolysis or erythrocyte pathology, for example, nitrite poisoning. We have observed splenic and hepatic haemosiderosis in wild Australian barramundi.

Blood

A number of parasites are described in fish blood, including *Haemogregarina* and *Cryptobia*, and similar agents may be expected in barramundi, particularly where sucking parasitic vectors such as *Argulus* and *Hirudinea* are present.

Diagnosis of Disease

In order to adequately investigate disease outbreaks in fish, and to certify populations free of specific diseases, our laboratory has adopted, over the past 6 years, a number of prerequisites, including: individuals trained and experienced in the diagnosis of diseases of fish; facilities for histopathological, virological, bacteriological, parasitological and toxicological examinations; support laboratory staff trained in the isolation and identification of fish pathogens; and access to specialised or reference laboratories and to individuals with specific expertise, and facilities, for example, electron microscopy, exotic pathogen reference collections.

Because of the complexity of fish diseases due to the interactions of infectious, non-infectious and environmental or managemental factors, in our experience full laboratory support has been found of major benefit when investigating outbreaks of disease.

In our laboratory, investigations of disease are undertaken in a specific sequence: (1) disease occurrence; (2) clinical signs and history; and (3) environmental factors.

On the basis of the above, the clinician may reach a diagnosis or provisional diagnosis based on previous experience or no diagnosis. Thereafter follows: (a) gross pathological examination; (b) histopathology, virology, bacteriology, parasitology, toxicology, other specialist examinations; (c) morphological and/or aetiological diagnosis; and (d) treatment or control. Failure to take all the above factors into account runs a risk of not identifying a major aetiological factor in the disease outbreak.

Laboratory Facilities

The following facilities are used in our laboratory for the investigation of diseases in fish and are in addition to those facilities present in many mammalian diagnostic laboratories. Tehnical details can be located in Plumb and Bowser (1983) and Humphrey and Langdon (1986).

Gross Pathology: Dissection area, dissecting microscope for sub-gross examinations and microdissections on small fish.

Histopathology: Facilities for fixing, paraffin impregnation and sectioning of tissues. Facilities for staining including special stains. Compound microscopes.

Virology: Cell lines known to be susceptible to the range of potential viruses. The range of barramundi cell lines available is unknown but our laboratory has an epitheloid cell line derived from barramundi heart, which is susceptible to EHN virus. Controlled low temperature incubators are essential. Media preparation and sterilisation facilities, and a control virus culture collection are also necessary.

Bacteriology: Controlleu low temperature incubators, media preparation and sterilisation facilities. Control cultures.

Parasitology: Fine instruments for dissecting and handling parasites. Fixatives, special stains, and mountains.

Quarantine: National and International

Significant initiatives and achievements related to the quarantine of live fish for control or treatment of infectious diseases have occurred over recent weeks in the Southeast Asian region (see Davy and Graham 1979, Anon 1983). While such initiatives are recognised the need for restrictions on movement of fish known to be infected by, or capable of carrying, diseases which will or may affect barramundi or other fish species is an issue which warrants continued consideration.

It is our contention that strict controls on movements of live fish should exist on a regional basis to prevent the inadvertent transfer of diseases which may severely limit or preclude intensive production of barramundi, as well as other fish species. This in no way implies that trade in live fish should stop, but that trade should continue and that the fisheries-related industries be safeguarded by a system of health certification and quarantine prior to movements. Such certification would, by necessity, involve the testing of ornamental fish as well as stocks of food fish as these are known to carry a number of serious pathogens, for example, *Edwardsiella tarda* and *E. ictaluri* (Humphrey et al. 1986) infectious pancreatic necrosis virus, and some, for example, gouramis, are known to be affected with the epizootic ulcerative syndrome virus (EUSV) (Frerichs et al. 1986).

Major quarantine issues for future consideration include: establishment of national disease status; restrictions on movements of diseased stock; treatment/disinfection prior to movements of all stock; health certification of broodstock; protocols for disease-free movements; legal basis for control/eradication of disease; effective disease notification (regional); health certification for ornamental fish; disease diagnostic facilities; research on treatment, control, eradication and prevention of disease.

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Diseases of Barramundi *(Lates calcarifer)* in Australia: A Review

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PAST research into the diseases of barramundi *(Lates calcarifer)* in Australia has been restricted to fish supplied by government biologists and commercial fishermen. The logistic problems associated with studying disease outbreaks in northern Australia continue to be immense and suitable material is obtained only with great difficulty, e.g. in cases of ankylosing spondylosis. Meaningful interpretation of pathological changes in organs and tissues depends on rapid fixation and is precluded by freezing and spoilage.

Based on overseas experience, the culture of barramundi in this country will result in the creation of conditions suitable for disease epizootics (particularly those caused by bacteria and protozoa) as well as nutritional deficiencies.

This paper attempts to review the disease findings of government and private agencies involved in the study of captive and wild barramundi in Australia. For purposes of discussion the term disease has been divided into infectious and non-infectious causes and known pathogens have been distinguished from potential pathogens which have not yet been associated with mortalities.

Results

Known Pathogens

Infectious agents known to have caused mortalities in barramundi in Australia are listed below. They include one bacterial, one fungal, two protozoan and one possible viral disease.

VIBRIO SPP. INFECTION

Vibriosis has been diagnosed in juvenile fish from a barramundi farm in north Queensland and in a wild adult fish from the Gulf of Carpentaria (Glazebrook and Campbell, unpublished data).

Clinical signs in juveniles included disorientation (swimming upside down), corneal oedema and clouding and reddening of the ventral abdomen. The adult fish showed focal and diffuse haemorrhages associated with being caught in a gillnet and rough handling.

Microscopically, tubular degeneration had occurred in the kidney and endothelial macrophages were swollen (with ingested bacteria).

Three species of *Vibrio* were isolated (viz. *vulnificus* biotype I, *harveyi* and *damsela*) from the kidney and *V. vulnificus* biotype I from heart blood (obtained by cardiac puncture).

Vibrio alginolyticus was also isolated from the heart blood and kidney of the adult fish with traumatic lesions.

SAPROLEGNIA SP. INFECTION

Juvenile barramundi being reared as part of an aquaculture course at the Capricornia Institute of Advanced Education in Rockhampton regularly developed saprolegniasis in 1984–85 (Cook and Unwin, pers. comm.).

Typically the fish are inactive and show white, cottony growths on the lateral aspects of the body and a loss of pigmentation when the fungus is removed.

The hyphae invade the epidermis and dermis where they attract a mild inflammatory response. Certain environmental conditions (viz. fresh water at a temperature less than 18°C) predispose the fish to this disease.

CRYPTOBIA SP. INFECTION

A single infection of *Cryptobia* sp. has been diagnosed in an adult fish from the Proserpine River near Mackay (Glazebrook and Campbell unpublished data).

The fish failed to thrive while in captivity and showed a chronic loss of weight (45 g in 1 month, original weight 800 g). The only visible external lesions were two cysts 8 × 5 mm and 3 × 1 mm on the gill lamellae where erosion had occurred.

Microscopically, the lamellar epithelium was hypertrophied as well as generalised inflammation and focal necrosis at the sites of encystment. Numerous 'comma' shaped unicellular organisms resembling

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Cryptobia sp. had been released from the cysts during sectioning.

There is evidence of leeches (family Hirudineae) attaching to barramundi in Australia (Rodgers 1986 pers. comm.). These organisms could transmit the hemoflagellates from one host to another.

In the case of 'Darwin ulcer disease' a rhabdovirus is currently being investigated by the National Fish Health Laboratory, Benalla, Victoria, as the possible cause of the skin ulcers in fish from the Mary, Cooper and East Alligator rivers in the Northern Territory (Humphrey and Langdon 1986 pers. comm.). Lesions were less severe in barramundi than in other species.

Potential Pathogens

A number of protozoa have been recovered from barramundi in Australia but not yet associated with mortalities.

Backhouse (1979) found white spots less than 1 mm in diameter on the skin and caudal fins of juveniles from the Fitzroy River, Rockhampton. The organisms, which measured 280–290 μm in diameter were uniformly ciliated and had a prominent cytostome. They were identified as *Icthyophthirius multifiliis*.

Cryptocaryon irritans has reportedly caused fin and epidermal lesions in cultured stock at the Queensland Fisheries Research Station, Walkamin, in north Queensland. In addition, *Chilodonella* sp. and *Trichodinia* sp. have been found on the gills of fry and fingerlings, apparently with no ill effect (Rodgers 1986 pers. comm.).

Ovoid cysts (1–2 mm diam) containing *Henneguya* spores were seen in the gills of 28–36 juvenile barramundi from the Fitzroy River, Rockhampton, by Backhouse (1979). The spores had a bifurcate tail and were 8–10 μm long.

'Old' cysts on the gills had elicited an inflammatory response consisting of neutrophils, coarse granulocytes and lymphocytes and were surrounded by a hyaline wall.

Recently, Glazebrook and Campbell (unpublished data) diagnosed cryptosporidiosis in juvenile fish collected from the Proserpine River and fed guppies for 4 months while in captivity. Different life stages of the coccidian parasite were attached to the intestinal mucosa and a few intracellular forms were present. The lamina propria had also been invaded with mononuclear cells.

The following metazoan parasites which are potentially pathogenic to barramundi have been found in association with *L. calcarifer* in Australia:

Larval cestodes (protecephalids) are very common in adult fish and were first reported in the intestine of juveniles from the Fitzroy River, Queensland, by Backhouse (1979).

Trypanorhynchs occur frequently in the body cavity of adults from the Gulf of Carpentaria and encystment in the peritoneal wall is always accompanied by fibrosis (Glazebrook and Campbell unpublished data).

Backhouse (1979) also recovered these larval nematodes (*Camallanus* sp.) from the intestine of a juvenile fish from the Fitzroy River. The worms were approximately 2.7 mm long and identified on the basis of their buccal processes. These worms can be expected to leave migration trails in the gut wall.

Monogean trematodes (*Diplectanum* sp.) have been associated with the erosion of the gill filaments in a fish from the Northern Territory (Backhouse 1979).

Little is known about digenean infections in Australian barramundi although Rodgers (1986 pers. comm.) has identified *Prototransversotrema steeri* from the skin of wild stock.

Crustaceans (*Ergasilus* sp.) found on the gills of wild barramundi (Backhouse 1979) have the potential to inhibit respiration and predispose fish to bacterial infection.

Non-Infectious Diseases

There are few reports of non-infectious diseases in wild barramundi and cultured fish seem to be more susceptible to nutritional deficiencies.

Only one tumor (a chondroma) has ever been seen in wild Australian stock (Glazebrook and Campbell unpublished data). The lesion was located on the bridge of the nose and between the eyes of an adult fish from the Bynoe River near Normanton in the Gulf of Carpentaria. Microscopically, the tumor was well defined and consisted of a cartilaginous matrix.

Nutritional deficiencies have begun to appear in cultured barramundi. Six out of a group of 60 fingerlings being reared in a plastic lined swimming pool in Cairns were exhibiting abnormal swimming behaviour, i.e. nearly vertical with exaggerated tail movements. These fish were not interested in food and showed no obvious internal or external lesions. Microscopically, bilateral degenerative changes (vacuolation) had occurred on both sides of the brain and the peripheral nerves were also affected. In the spinal cord, gliosis, i.e. swelling of the glial cells, was evident, particularly ventrolaterally. There was strong evidence to suggest that fish being fed to the fingerlings was high in the enzyme thiaminase. A dietary change has since corrected the problem.

Ankylosing spondylosis is a degenerative condition of the spinal column characterised by deposition of the bone in the intervertebral spaces thus fusing the vertebrae and the development of a thick, gelatinous mass of loose connective tissue around the affected part of the spine. The cause is unknown (Lester and Kelly 1984).

Discussion

From the range of disease agents and/or factors identified in Australian barramundi so far, there seems to be considerable overlap with findings from other countries.

Vibriosis is a serious condition in farmed barramundi in Singapore (Cheong et al. 1983) where *V. alginolyticus* and *V. parahaemolyticus* have been implicated and in Thailand (Chinabut and Danayadol 1983). The *Vibrio* spp. isolated in Australia (*V. damsela* and *V. vulnificus* biotype I) have been associated with mortalities in damsel fish (Love et al. 1981) and certain species of shark (Grimes et al. 1984) respectively. They both produce extremely potent extracellular cytolysins.

Saprolegniasis also occurs in Thailand (Chinabut and Danayadol 1983), and is treated with malachite green and formalin. *Amyloodinium* sp. infections are treated with a higher dose of formalin.

Cryptobia sp. infections have previously been reported in farmed rainbow trout in California, where *Saprolegnia parasitica* was a secondary invader (Wales and Wolf 1955). Gills were covered in a white, gelatinous exudate in contrast to the Australian condition where cysts had formed and a 'bottleneck' situation had developed in vessels supplying the gills.

Ichthyophthirius multifiliis and *Cryptocaryon irritans* are causative agents of freshwater and marine 'white spot' in Thailand (Chinabut and Danayadol 1983) and almost certainly in other countries. *Trichodina* spp. appear to be a particular threat to barramundi fry in Australia (Rodgers 1986 pers. comm.).

Cryptosporidiosis has only been diagnosed once before in fish (Hoover et al. 1981) where it was not associated with an inflammatory response.

There is little evidence to suggest that larval cestodes and nematodes will cause nervous problems in cultured barramundi in Australia. However, monogean flukes have been shown to be a problem in other cultured *Lates* spp. (Paperna 1980). In addition, crustacean parasites such as *Ergasilus* sp. can cause significant skin and gill damage when present in large numbers (Paperna 1980).

The importance of research into the nutritional requirements of captive barramundi is borne out by the rapid appearance of a vitamin deficiency. Fortunately, this sort of problem can be easily corrected. A similar condition has been reported in cultured herring (Blaxter et al. 1974).

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